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Electromagnetic Environmental Effects Compendium

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Electromagnetic Environmental Effects Compendium

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This report summarizes the electromagnetic environmental effects (E3) program of the U.S. Army Communications-Electronics Command (CECOM). The report includes background information on CECOM's role in the Army E3 program, presents the approach used to identify the electromagnetic environment, summarizes E3 criteria (i.e., the CECOM model electromagnetic environment), and provides a sample E3 assessment. The report also discusses electromagnetic trends and their implications.

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ELECTROMAGNETIC ENVIRONMENTAL EFFECTS COMPENDIUM

ABSTRACT

This report summarizes the electromagnetic environmental effects (E³) program of the U.S. Army Communications-Electronics Command (CECOM). The report includes background information on CECOM's role in the Army E³ program, presents the approach used to identify the electromagnetic environment, summarizes E³ criteria (i.e., the CECOM model electromagnetic environment), and provides a sample E³ assessment. The report also discuses electromagnetic environment trends and their implications.

1 INTRODUCTION

The electromagnetic environment (EME) comprises all man-made and natural electromagnetic radiation. It includes emanations from emitters at the lowest alternating current to the highest radio frequency (RF), whether hostile or friendly, and all modes of modulation and spectrum usage. Electromagnetic environmental effects (E³) are the impact of the EME upon the operational capability of military forces, equipment, systems, and platforms. E³ encompasses all electromagnetic disciplines, including electromagnetic compatibility (EMC) and electromagnetic interference (EMI); electromagnetic vulnerability; electromagnetic pulse (EMP); electronic counter-countermeasures, hazards of electromagnetic radiation to personnel, ordnance, and volatile materials; and the natural phenomena effects of lightning and p-static.

The impacts of E³ can range from irritating to catastrophic. Noise on a voice telephone call, transmission errors on a data telephone call, and the loss of a flight control system on an aircraft are all E³. Electronic devices such as digital computers are now present in quantity in every major military system. By the year 2000, embedded computers will be prevalent in all systems including such items as the soldier's rifle. Each electronic device on the battlefield is both an emitter that may cause E³ in other equipment and a potential source of vulnerability if it malfunctions due to E³. This situation has resulted in Department of Defense (DoD) programs to ensure EMC among friendly forces and to exploit E³ to degrade enemy force capabilities.

2 BACKGROUND

2.1 THE ARMY E³ PROGRAM

E³ programs have been conducted by DoD since the 1930s. In 1960, concern over the effects of radio frequency interference (RFI) prompted DoD to initiate a program to ensure that EMC was considered as an integral part of the design, development, procurement, and maintenance of communications-electronics systems. DoD Directive 3222.3 assigned responsibility for EMC standards and specifications to the Navy, EMC measurement techniques and instrumentation to the Army, and EMC analysis and database support to the Air Force. The

Air Force was designated the administrative agency for the joint DoD Electromagnetic Compatibility Analysis Center (ECAC).

Army Acquisition Executive (AAE) Policy Memorandum 91-3, *Army Electromagnetic Environmental Effects (E^3) Program Implementation*, was promulgated by the Department of the Army (DA) on 22 January 1991. This memorandum assigns technical responsibility to develop and maintain E^3 scientific and engineering personnel, perform E^3 analyses, and provide E^3 test facilities to the U.S. Army Materiel Command (AMC). The memorandum directs the establishment of E^3 requirements boards to analyze E^3 criteria, review E^3 program procedures, and provide recommendations to materiel development program sponsors. Program sponsor is a generic term for the actual manager of the materiel development program at its base level, e.g., the product, project, or program manager (PM). The AAE policy memorandum states that it remains in effect through 31 December 1992; however, it is ongoing and still remains in effect, as no new E^3 program requirements and policy have emerged to supplant the existing requirements.

E^3 criteria (i.e., standards) are that subset of the anticipated EMEs to which a system could be designed to prevent degradation under combat, training, and storage conditions. AAE Policy Memorandum 91-3 requires that the E^3 criteria for a system include critical frequencies (or wavelengths), expected duration and field strengths (or power density if a propagating wave), and, when applicable, pulse and modulation characteristics. These criteria define a baseline level of electromagnetic protection.

2.2 THE CECOM E^3 PROGRAM

AMC has delegated its E^3 functions to each of the major Army commands, including the U.S. Army Communications-Electronics Command (CECOM). Within CECOM, these functions have been delegated to the Research, Development and Engineering Center (RDEC) Space and Terrestrial Communications Directorate (S&TCD).

CECOM has directed S&TCD to support the PMs of the Program Executive Offices (PEOs) for Communications Systems (COMM), Command and Control Systems (CCS), and Intelligence and Electronic Warfare (IEW). Senior-level technical staff from the CECOM RDEC are assigned to provide technical support for the E^3 program. Depending on the types of electromagnetic effects, there may be requirements for studies, analyses, tests, and/or data measurements.

In accordance with DA policy, CECOM addresses E^3 issues through the use of integrated teams acting as formal E^3 requirements boards. These E^3 review boards (E3RBs) are advisory bodies supporting product decisions driven by the EME. E3RB membership consists of personnel from the Army command performing the materiel development (e.g., the CECOM RDEC), the program sponsor organization, the user community, and, when necessary, advisory members. The materiel developer hosts the meetings and supplies the board chairperson. At the end of June 1993, there were eleven major Army programs supported by CECOM E3RBs. The E3RBs are listed in Table 1.

Table 1. CECOM E^3 Boards

E^3 Board	Board Chairman	PEO	PM Organization	User's Representative
EPLRS JTIDS	B. Kowaluk S&TCD	COMM	ADDS	CPT L. Hernandez J. Keever
GPS	K.H. Brockel S&TCD	COMM	GPS	MAJ W. Reiner
MSE	E. Roswell S&TCD	COMM	MSE	CPT W. Chatman W.E. Kelley
SINCGARS	R. Hoverter S&TCD	COMM	SINCGARS	G. Strellner
AFATDS	H. Kaunzinger C2SID	CCS	FATDS	J. Parker
ASAS	H. Kaunzinger C2SID	CCS	ASAS	J. Ordway
CSSCS	H. Kaunzinger C2SID	CCS	CSSCS	MAJ M. Page
FAADC2I	H. Kaunzinger C2SID	CCS	ADCCS	MAJ J. Ivy
MCS	H. Kaunzinger C2SID	CCS	OPTADS	COL T. Dials
JSTARS	B. Charnick IEW	IEW	JSTARS	MAJ C. Ershem

The program sponsor uses the E3RB to assess and document, by use of analyses and/or test, that the system meets its E^3 criteria. Key activities of the review boards are identifying the range of anticipated electromagnetic environments, determining the initial E^3 criteria, quantifying environmental impacts, and planning corrective actions to reduce vulnerabilities. The E3RB determines the initial E^3 criteria, evaluates the feasibility of meeting the criteria, conducts mission and hardening-level trade-off analyses, and documents its recommendations to the program sponsor. The program sponsor and user representative are responsible for including E^3 criteria acceptable to the E3RB in the applicable acquisition documents at as early a point in time as practical.

E3RBs are required to provide their recommendations and comments to program sponsors in writing. Any E^3 issues or problems that can not be resolved between a review board and its program sponsor must be passed upward for resolution. The initial step is to forward the matter to the relevant PEO. Any concerns not resolved by the PEO are forward to the Assistant Secretary of the Army (Research, Development and Acquisition), Director, Program and Vulnerability Assessment. Depending upon the E^3 issues in question, a CECOM working group may also be formed to facilitate resolution.

A paper, written by CECOM personnel, *Army E^3 Program: A Process Focused on Teaming* (provided as Attachment 1), described the establishment of the CECOM E3RBs and directed attention on the power of the total quality management (TQM) concept that provides a team approach for working group processes. The E3RBs use the tools of TQM to define the electromagnetic environment in which the systems must survive, address the problems associated with co-site interference, provide a team approach for E^3 assessments, determine the potential vulnerability, and develop action plans for the respective program sponsors.

As a result of a DA tasking in 1992, the Army Materiel Systems Analysis Activity (AMSAA) prepared an E^3 program assessment survey in order to review the E^3 program and prepare for a Spring 1993 General Officer Review Council meeting with the Army Vice Chief of Staff. The E^3 program assessment survey solicited information on the status of the system E^3 efforts, feedback, and general comments; the memorandum was issued by DA (Program and Vulnerability Assessment) to PEO COMM, PEO CCS, and PEO IEW, on 22 December 1992. Senior-level technical staff from the CECOM RDEC provided technical support for the survey, which was completed in January 1993. The E^3 program assessment survey addressed 47 questions related to efforts in four E^3 areas (general program/policy, requirements definition, testing, and evaluation) and included feedback (evaluation/assessment and improvement suggestions) and comments. The questions, particularly those relating to E^3 criteria, attempted to identify the EME for a system in relation to EMI, EMC, lightning effects, and EMP. The review council met on 13 April 1993 and AMSAA reported that major acquisition programs are efficiently finding and fixing E^3 problems using current E^3 guidance but that non-major acquisition programs are having limited success in adapting E^3 guidance. A memorandum was initiated by Mr. J. Kreck (AMC) on 8 June 1993 to provide guidance procedures for the non-major system acquisition tasks and the interaction with the material developers, combat developers, and E3RBs.

3 ELECTROMAGNETIC ENVIRONMENTS

The first step in an E^3 assessment is to estimate numerical values to quantify the EMEs. Often, a single EME estimate is adequate because simple inspection identifies a situation combining the greatest functional performance requirements with the most severe EME. The data needed for estimating may be obtained from sources such as previous E^3 analyses, laboratory tests, field measurements, field exercises, and battlefield experience (e.g., Granada, Panama, and Kuwait). EME estimates may also be influenced by policy and requirements documents. MIL-STD-461, MIL-STD-462, and system-specific specifications, waivers, and fielding-concept documents are data sources in this category.

One of the basic factors defining the EME is the strength and relative location of all emitters in relation to the system being evaluated. To determine this, one would need to know the composition of the friendly and enemy forces, the types of civilian emitters present, and the relative coordinates of all emitters. It is neither practical nor appropriate to attempt to obtain detailed information of this nature. Friendly and enemy forces are likely to be coalition forces comprising units from several countries. The post-Cold-War free market in military equipment makes it impossible to predict the specific characteristics of the emitters that will be used by the opposing forces. If specific information on civilian emitters exists, it will not be retrievable until military deployments and missions are planned. Therefore, the only practical solution is approximation based on professional judgment and safety factors (i.e., weighting factors) applied during analysis to address the level of uncertainty in the data.

S&TCD has developed a model EME to be used for performing E^3 assessments of terrestrial systems. This EME is based on U.S. Army Electronic Proving Ground (USAEPG) publication number EMETF 91-06-001 (S), *Data Packet Electric Field Strengths and Technical Data for Europe VI Simulated Tactical Deployment Equipment (U)*, dated June 1991. This publication can be used as a source for data on both friendly (Blue) and enemy (Red) emitters. The publication does not include data on civilian (Gray) emitters. The publication classifies emitters into four groups: Blue fixed, Blue mobile, Red fixed and Red mobile. Only emitters capable of producing an electric field (E-Field) strength of at least five volts per meter (V/m) at a distance of 25 meters were extracted from the computer database for inclusion in the publication.

S&TCD reviewed the publication and decided that a distance of 25 meters for Red emitters is not a realistic EME criterion. This distance has been changed to 1500 meters for the model environment. In addition, the effects of some emitters have been reduced because it is improbable that the equipment CECOM would evaluate will be deployed in the main beam of the emitter antenna. The field strengths given in the EMETF publication are purported to be average values. S&TCD believes that calculation of the average field strengths for radar frequencies above one gigahertz (GHz) must consider the emitter's duty cycle. Therefore, a one millisecond (typical) duty cycle was used to convert the peak to average field strength. The average field strength is indicated by the E3RB envelope as shown in Figure 1.

The S&TCD model EME for the Red and Blue emitters is depicted in Figures 1 through 4. The model E^3 criteria derived from these figures (with red emitters at 400 meters) are depicted in Figure 5.

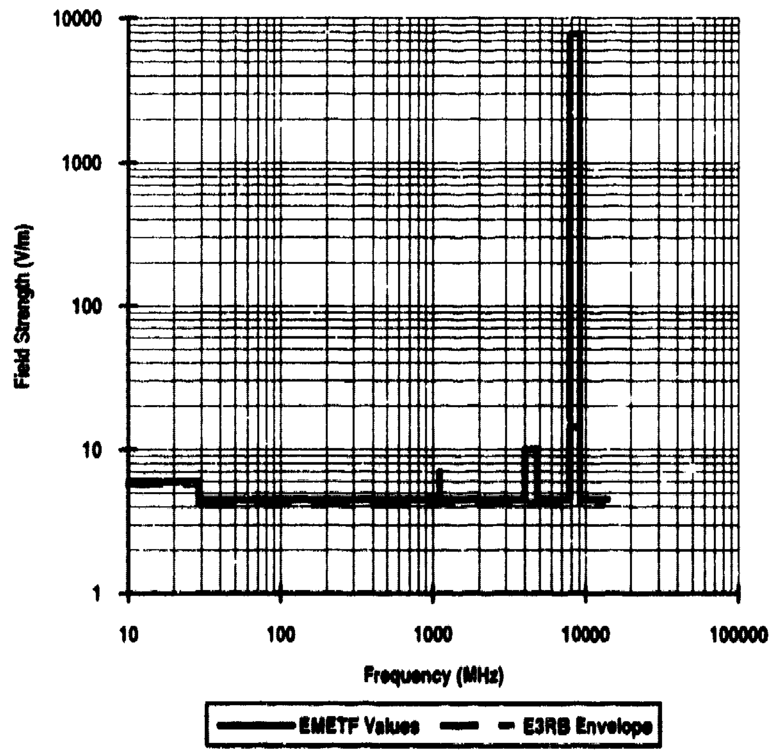

Figure 1. Average Blue Mobile Emitter Field Strengths (25 Meters)

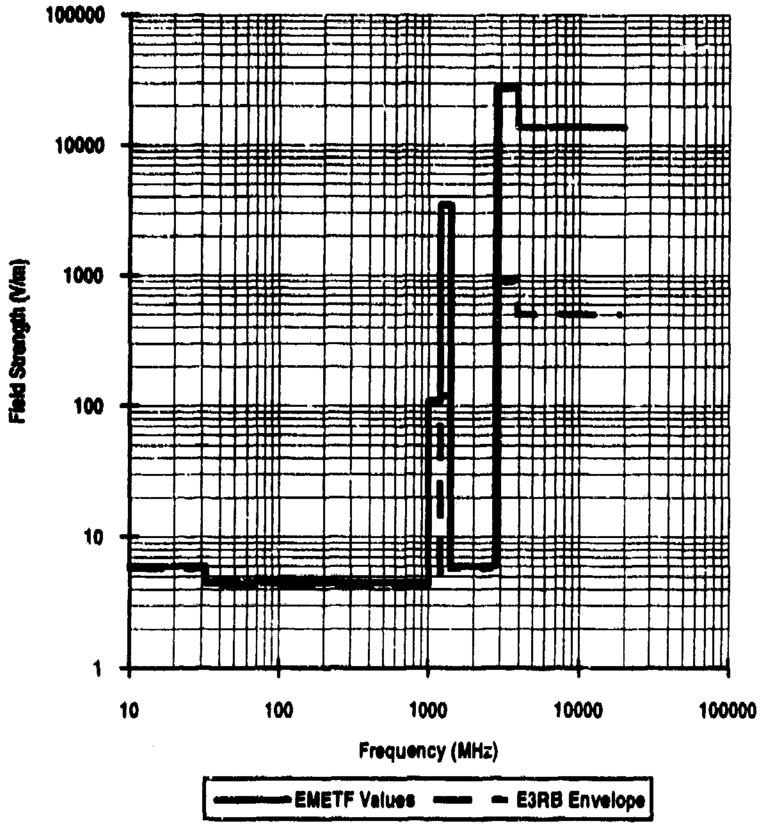

Figure 2. Average Blue Fixed Emitter Field Strengths (25 Meters)

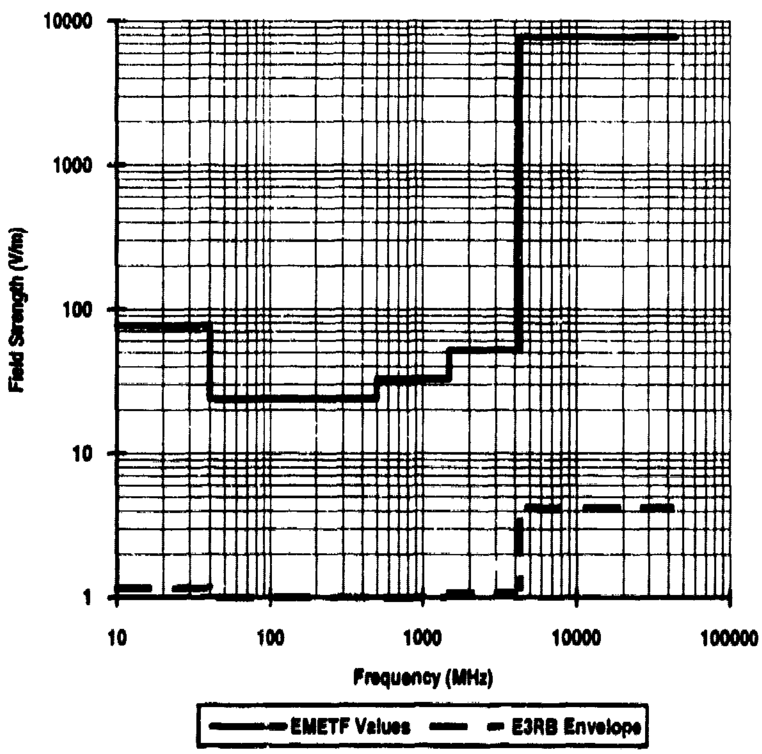

Figure 3. Average Red Mobile Emitter Field Strengths (1500 Meters)

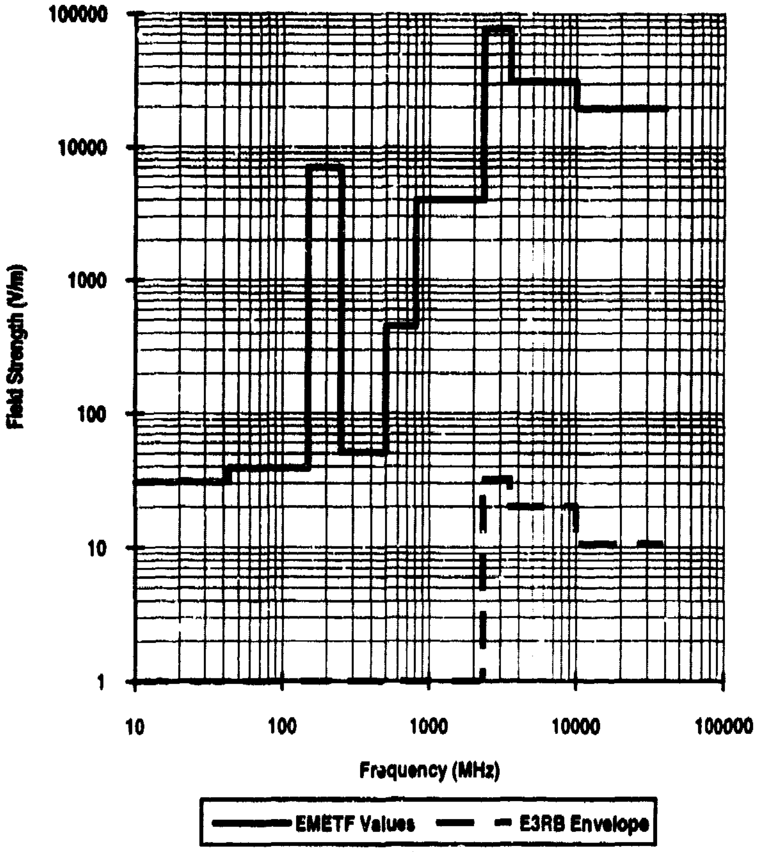

Figure 4. Average Red Fixed Emitter Field Strengths (1500 Meters)

Field Strength (V/m)													
Frequency	10 kHz	30 kHz	100 kHz	300 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
Blue Mobile (25 m)	6	6	6	6	6	6	6	6	5	5	5	5	15
Blue Fixed (25m)	6	6	6	6	6	6	6	6	5	5	120	1000	500
Red Mobile (400m)	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	2	2	3	4.5	20
Red Fixed (400m)	2	2	2	2	2	2	?	2	2	2	2	130	500
Maximum	6	6	6	6	6	6	6	6	5	5	120	1000	500
E3 Criteria	2	2	2	2	2	2	2	2	2	2	5	6	6

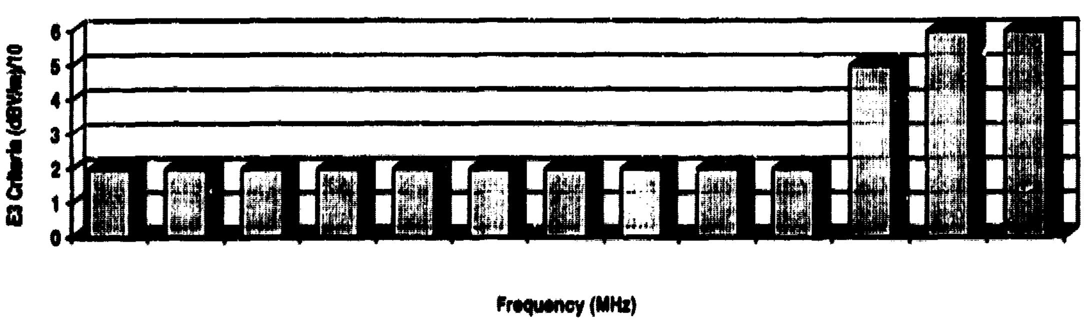

Figure 5. E[3] Criteria

4 CO-SITE CONSIDERATIONS

Co-site interference problems may occur when systems are located in relative proximity to each other. The steps taken to resolve the problem can range from procedural changes to major equipment redesign. If, for example, a transmitting antenna interferes with a radio receiver, it may be possible to move the antenna away from the receiver. Alternatively, an operational procedure could be instituted to prevent simultaneous transmission and reception. Redesign might involve increasing the shielding or reducing leakage from penetrations in shelter walls, platforms, and transit cases.

Products such as video display terminals (VDTs) generate magnetic fields (e.g., the fields from deflector coils, power supplies, high-voltage transformers, and circuit boards). This fact should be considered when VDTs are collocated with other equipment. For example, adding a nondevelopmental item (NDI) computer (perhaps an ordinary commercial model) to an existing equipment shelter could create problems. If the computer interferes with the other equipment within the shelter, it may be possible to replace the high-emission NDI computer with a low-emission militarized model. This solution may be more cost-effective than upgrading all of the impacted equipment to allow it to cope with the inexpensive computer's emissions.

The emission limits for civilian computers are established by the Federal Communications Commission (FCC). At a distance of approximately one meter, computers intended for commercial sites must meet a 60-decibel (referenced to microvolts per meter, dBµV/m) limit (Class A); computers intended for residential use must meet a 50-dBµV/m limit (Class B). NDI computers used by DoD, even if ruggedized, must conform to the FCC Class A limit. MIL-STD 461, *Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interence*, defines emission limits for MIL-SPEC equipment and should be used for a new design acquisition. MIL-STD-461A Notice 4 (EL), *Electromagnetic Interference Characteristics, Requirements for Equipment, Subsystem and System*, covers the requirements and test limits for many of the present electronic, electrical, and electromechanical systems and subsystems.

Problems exist when an NDI computer is located next to sensitive receiver antennas on an open vehicle or in a tent. S&TCD conducted tests to determine the effects of computer-radiated emissions on net radios. A spectrum analyzer was used to measure the dBm signal level of the emissions as they would be received by the net radio. The FCC commercial and residential limits for computer emissions were normalized to one meter (plotted in Figure 6 for the frequency range of 30 to 88 MHz). MIL-STD 461A, Notice 4 (EL) narrowband radiation emission (REO2) limits, were also plotted for the one-meter distance. Measured net radio sensitivities at -108 dBm, -111 dBm, and -116 dBm were then plotted (shown in the bottom portion of Figure 6). The net radio data is based on the use of a whip antenna. Figure 6 illustrates the fact that, at a one-meter separation distance, neither equipment complying with the MIL-STD 461A limits nor equipment complying with the FCC limits have low enough emission levels to avoid interfering with net radios. The MIL-STD limits of 21.25 dBµV/m at 30 MHz and 28.8 dBµV/m at 90 MHz exceed the values required for a -111 dBm net radio sensitivity by 24 dBm.

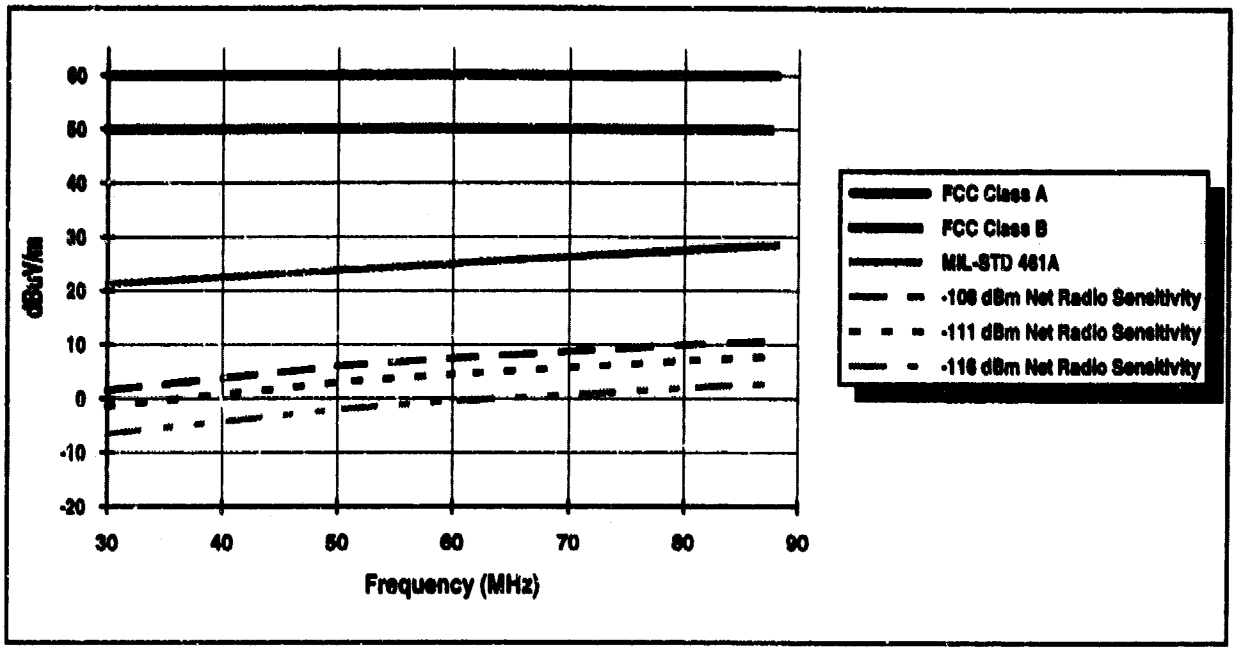

Figure 6. FCC and MIL-STD 461A Radiation Emission Limits Compared to Net Radio Sensitivity

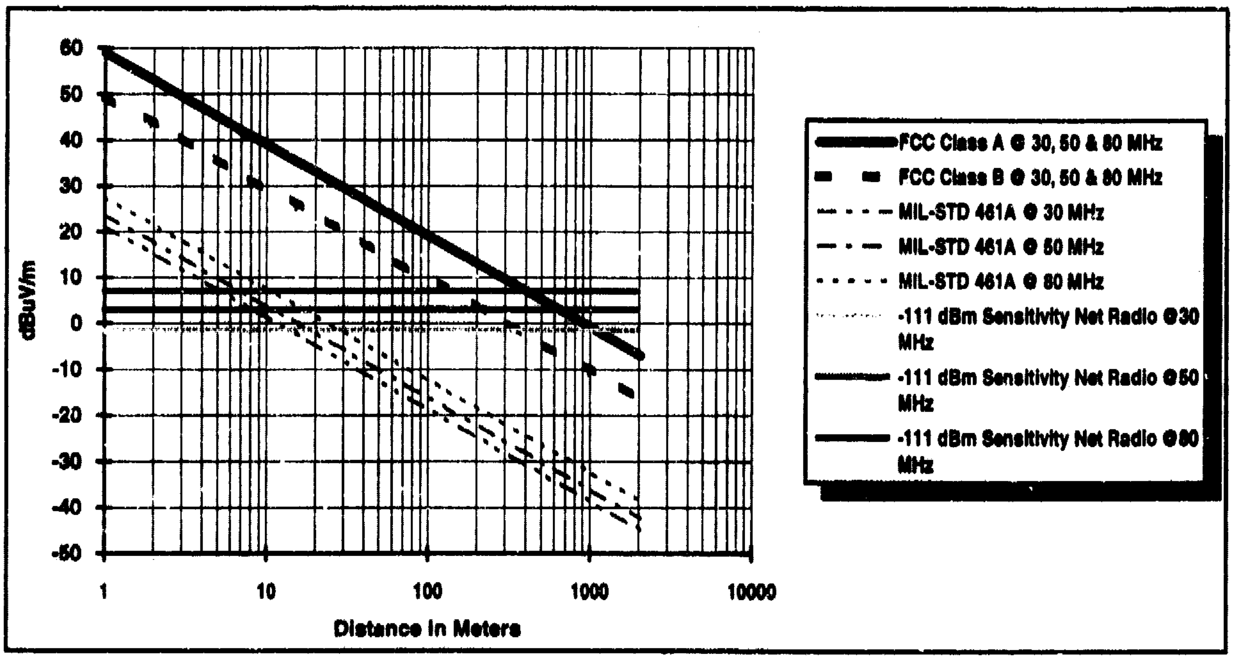

Figure 7. Radiation Emission Limits and Net Radio Sensitivity as a Function of Distance

A normal response to co-site interference problems is to increase the physical distance separating conflicting devices. Figure 7 plots the -111 dBm sensitivity limit, and the FCC and MIL-STD 461A emission limits, for 30, 50, and 80 MHz over separation distances from 1 through 2048 meters. To produce the plot, the one-meter FCC and

MIL-STD 461A data from Figure 6 was extrapolated (20-dB decrease per decade) for distances from 2 to 2048 meters. From the plot, it can seen that devices having emission limits conforming to MIL-STD 461A need separation distances between 10 and 15 meters; commercial devices need greater separation distances. The implication drawn from Figure 7 is that co-site interference problems can be expected to develop in greater quantity whenever soldiers bring personally-owned commercial computers with them into battle and operate them near radio receivers.

In addition to radiated tests, a series of co-site interference tests and measurements were conducted at Tobyhanna (Pennsylvania) Army Depot to determine the potential interference effects when the Joint Tactical Information Distribution System (JTIDS), the Enhanced Position Location Reporting System (EPLRS), the Single Channel Ground and Airborne Radio System (SINCGARS), and Mobile Subscriber Radio-telephone Terminals (MSRTs) are mounted in vehicular shelters. Tests were conducted in a hardwired mode rather than a radiated mode. JTIDS terminals, EPLRS terminals, SINCGARS radios, and MSRTs were each subjected to interferring transmissions from combinations of the other equipment. Prior to the co-site tests, interference tests between SINCGARS radios and MSRTs disclosed interference problems. Operational capability is provided, but the units must be operated sequentially, not concurrently. Interference tests between SINCGARS radios and MSRTs were not reexamined for the closed-loop tests at Tobyhanna Army Depot. Closed-loop tests using the operational procedure, revealed that there were no detrimental co-site effects of the subject equipment upon each other, but there was some interference between two collocated EPLRS terminals. However, the interference of an EPLRS transmitter upon a collocated EPLRS receiver only produced a three-percent reduction in receiver throughput and would not interfere with normal tactical operation. Additional antenna separation vertically or horizontally might improve the performance.

5 E³ ASSESSMENT

The goal of the Army's E³ program is to ensure that the EMEs encountered during war and peace do not prevent Army equipment from accomplishing its intended mission. To help program sponsors acquire systems meeting this goal, the Army disseminated an E³ assessment methodology in September 1991; it is provided as Attachment 2. This methodology is a tool for program sponsors to use in meeting their E³ program requirements. The requirements include:

- Determining the anticipated EMEs and establishing E³ criteria
- Identifying mission degradation and/or safety hazards due to E³
- Developing a short-term plan to quantify and address mission degradations and safety hazards
- Developing a long-term plan to conduct system evaluation and/or testing based on agreed-upon E³ criteria
- Incorporating E³ protection into the life cycle control process.

The E³ assessment methodology provides PMs and others with an analytical procedure for conducting first-order E³ assessments of systems. While the use of this methodology is optional, it is very attractive. The methodology can provide indications of major E³ problems at an early point in the development program. This enables preventive and corrective actions to be taken when they have the lowest life-cycle cost and the least schedule impact. The methodology is illustrated in flowchart form in Figure 8.

The first part of the E³ assessment is data gathering. This consists of defining the EME and the E³ criteria for the system, acquiring system and subsystem data (e.g., identifying types and shielding of platforms, equipment and interfaces, cases, cables, and component circuit sensitivities), obtaining system mission and function descriptions, and reviewing known E³ problems.

The second part of the assessment is subsystem analysis. E³ protective measures included in the design are evaluated in relation to the system's E³ criteria to determine whether potential susceptibilities to the EME exist. If any are disclosed, an analysis of their potential impact on the overall system must be performed. The potential impact is examined to determine system vulnerability and quantify the potential for mission degradation and safety hazards. Action by the E3RB and PM may be required if vulnerabilities are identified. Key considerations in taking corrective action would be the type of impact and cost, time, and level of effort required to reduce susceptibility. If the conclusion from the initial assessment is that the potential vulnerabilities are unacceptable, the E3RB will develop an accelerated short-term plan to quantify the potential system limitations and devise a corrective action plan.

If the program sponsor accepts the vulnerability quantification and the corrective action plan, work begins. If not, CECOM working groups can be formed to attempt to resolve differences between the sponsor and the E3RB. Should the differences not be reconciled, a formal appeal process must commence to apprise relevant authorities of the issues and to ensure timely resolution of the differences.

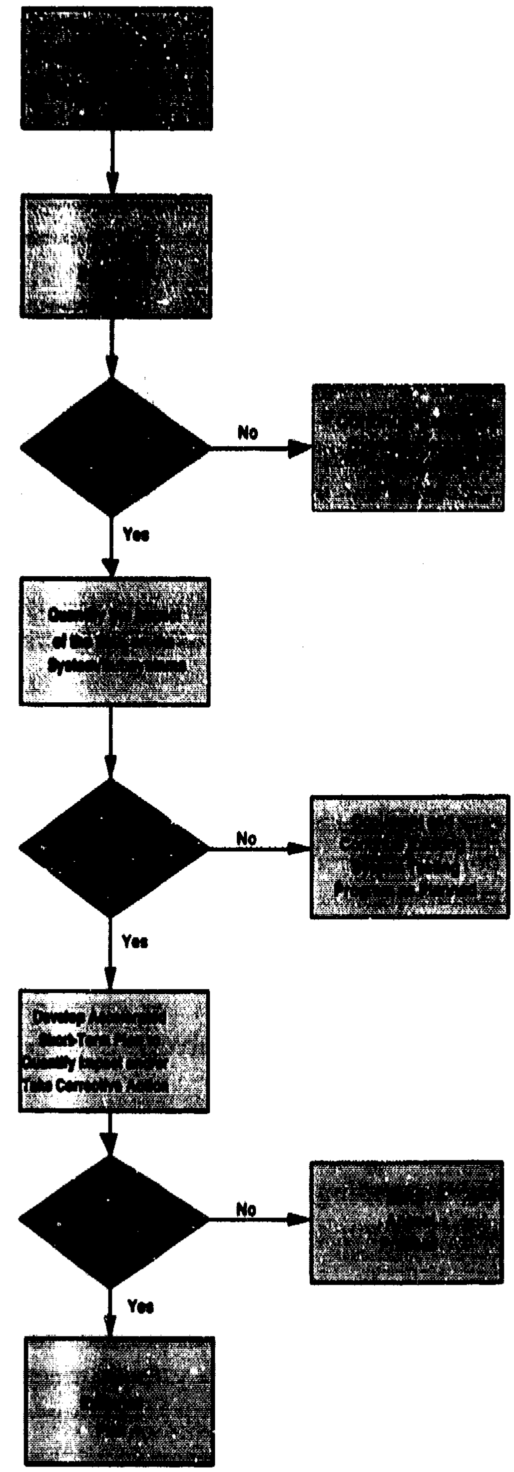

Figure 8. E³ Assessment Process Flow Diagram

5.1 SUBSYSTEM ANALYSIS CATEGORIES

A subsystem consists of circuitry within a case with cables connecting it to other components within a system. The subsystem has been designated as the base element from which an E^3 analysis will begin. The E^3 susceptibility analysis utilizes the following eight categories:

1. E^3 criteria (defines the EME within which a system will operate)

2. Platform loss (the degree of shielding provided by the mounting environment, e.g., shelter or building)

3. Cable shielding (a function of the types and quality of cables used to interconnect subsystems)

4. Interface attenuation (a measure of the attenuation provided by filtering the circuitry of the subsystem at the interface point between subsystem cabling and circuitry)

5. Cable length (related to the degree to which the EME affects the circuitry by coupling through the cables)

6. Case shielding (a measure of the case's protection against EME penetration and corresponding adverse effects on the circuitry through coupling)

7. Circuitry sensitivity (a measure of a circuit's threshold of susceptibility to the EME based on the subsystem's electronics)

8. Weighting factor (an additional degree of safety for critical subsystems to compensate for lack of data, user expertise, or other uncertainties).

These eight categories are quantified logarithmically using EME values in dB, thereby allowing the various factors to be added. The parameters used for the categories (excluding category 8) are frequency dependent and may have different values; e.g., a cable has different characteristics as it is subjected to various frequencies. As depicted in the subsystem analysis worksheet (Table 2), the frequency spectrum has been uniformly separated into 11 frequency bands (by decade) from 10 kHz to 10 GHz; applying values to a subsystem under analysis will yield a subsystem evaluation total. To determine the subsystem evaluation total, a worst-case scenario is used to select the largest dB value for EME effects on the circuitry. This total can be compared to evaluation criteria from which a determination on a subsystem's susceptibility may be made. A subsystem having a positive evaluation total will show susceptibility to EME; a subsystem having a zero evaluation total will require additional testing to determine if there is a susceptibility problem. A negative evaluation total indicates that susceptibility is not likely.

5.2 E^3 ASSESSMENT METHODOLOGY EXAMPLE

An E^3 assessment for the Global Positioning System (GPS) was completed by the E3RB and is provided as Attachment 3. The report documents the EME and E^3 criteria for the manpack GPS receiver, the small lightweight GPS receiver (SLGR), and the precision lightweight GPS receiver (PLGR). The report assesses the ability of these three receivers to function in the GPS environment. The analysis was based on the E^3 assessment methodology defined in Attachment 2 and on the E3RB team approach for developing the environment described in Attachment 1.

Table 2. Subsystem Analysis Worksheet

Subsystem: ______________________________

LINE NO.	ITEM	COMMENTS	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
1.	E^3 Criteria												
2.	Platform Loss												
3.	EME Inside Platform	Enter the sum of line 1 and line 2 here and also on line 10.											
4.	Cable Shielding												
5.	Interface Attenuation												
6.	Cable Length												
7.	Cable Subtotal	Add lines 4, 5, and 6 and enter the result here.											
8.	Case Shielding												
9.	Subsystem Shielding	Enter the larger of line 7 or line 8.											
10.	EME Inside Platform	(From line 3)											
11.	Circuit Sensitivity												
12.	Weighting Factor												
13.	Subsystem Evaluation Total	Add lines 9, 10, 11, and 12. Enter the result here and on the system summary worksheet.											

Evaluation:

- If subsystem evaluation total is greater than +3, subsystem susceptibility to EME is likely.
- If subsystem evaluation total is between +1 and +3, susceptibility to EME is possible.
- If subsystem evaluation total equals 0, susceptibility to EME can not be determined.
- If subsystem evaluation total is less than 0 (negative), susceptibility to EME is not indicated.

The E3RB considered the EME, emitters, and electromagnetic phenomena that constitute a potential cause of malfunction or damage to the GPS receivers. The E3RB modified the standard EME based upon the expected battlefield scenario and the specific system mission for the GPS receivers. The E3RB made engineering judgements to disregard emitters if the GPS receivers were unlikely to be in the main beam of certain antennas and to convert field strengths from peak to average values. In addition, field strengths at 400 meters were used where it seemed improbable that GPS receivers would be as close as 25 meters to the antennas of certain emitters. The GPS environment (modified EME data for the GPS receivers) was summarized and listed in Figure 5 and Attachment 3's Table 1.

The following subparagraphs illustrate how the generic E^3 assessment methodology in Figure 8 was applied to the GPS environment. The first phase of the methodology, data gathering, is straightforward and has been omitted from this example.

The GPS environment is used to establish the E^3 criteria, and a subsystem analysis is performed for each of the receiver subsystems. The EME total for each subsystem is evaluated to determine if there is a potential susceptibility problem.

In order to view the details of a subsystem analysis, an assessment example on the GPS SLGR was selected for a representative analysis. As an aid in selecting the proper data for each of the eight GPS data category areas (Attachment 3), an extra column (comments) was added to the subsystem analysis worksheet to identify the item description or criteria selection that was used in determining the proper assessment data from Attachment 2. Also, the analysis is performed in three steps on the subsystem analysis worksheet table: (1) the entry for entered values (Table 3), (2) the subtotal for the addition of data (Table 4), and (3) the complete worksheet (Table 5). The first step of the SLGR subsystem analysis starts with Category 1, the E^3 criteria, followed by the other seven categories to be listed on the entry worksheet. The terms "category numbers" and "line numbers" are synonymous.

5.2.1 Step 1

Line 1 (or Category 1), E^3 Criteria, is the data (EME value) extracted from blue mobile/fixed and red mobile/fixed emitters. The EME values for the emitters and the E^3 criteria are listed in Figure 5 and Attachment 3's Table 1. The row labeled "maximum voltage/meter (V/m)" identifies the maximum (worst-case) field strength for the emitters at each of the frequencies from 10 kHz to 10 GHz. EME values for the E^3 criteria (on the next row and on the bar graph) are determined from the field strength values throughout the applicable frequency range. For example, if the field strength is 6 V/m (Figure 5 at 10 kHz), the next highest value of 10 V/m (refer to Attachment 2's Table 1) is used for the field strength value (20 dBV/m); hence, an EME value of 2 is observed in the EME column (for each increase of 10dBV/m in field strength, the EME value increases by 1). The E^3 criteria values are entered on the worksheet. The seven remaining category areas for the SLGR are selected in accordance with the criteria in the comments column from Attachment 3's Tables 2 through 8.

Line 2, Platform Loss (see Attachment 2's Table 2), is representative of the shielding for the SLGR. With reference to the platform loss table under the item description column for manpack (no shielding), the EME values are observed at all the frequen

Table 3. Step 1 in Completion of Subsystem Analysis Entry Worksheet

Subsystem: Small Lightweight GPS Receiver (SLGR)

SUBSYSTEM ANALYSIS WORKSHEET													
			FREQUENCY										
LINE NO.	ITEM	COMMENTS	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
1.	E^3 Criteria	Figure 5	2	2	2	2	2	2	2	2	5	6	6
2.	Platform Loss	No shield	0	0	0	0	0	0	0	0	0	0	0
3.	EME Inside Platform	Enter the sum of line 1 and line 2 here and also on line 10.											
4.	Cable Shielding	Closely spaced	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
5.	Interface Attenuation	Power line	-3	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
6.	Cable Length	30 feet	-7	-5	-3	-2	-1	-1	-1	-1	-1	-1	-1
7.	Cable Subtotal	Add lines 4, 5, and 6 and enter the result here.											
8.	Case Shielding	single case, no untreated hole	-14	-13	-12	-11	-10	-9	-8	-7	-7	-6	-6
9.	Subsystem Shielding	Enter the larger of line 7 or line 8.											
10.	EME Inside Platform	(From line 3)											
11.	Circuit Sensitivity	CMOS/RF	1	1	1	1	0	1	1	1	-1	-1	-1
12.	Weighting Factor	Minimal/low	1	1	1	1	1	1	2	2	2	2	2
13.	Subsystem Evaluation Total	Add lines 9, 10, 11, and 12. Enter the result here and on the system summary worksheet.											

Evaluation:

- If subsystem evaluation total is greater than +3, subsystem susceptibility to EME is likely.
- If subsystem evaluation total is between +1 and +3, susceptibility to EME is possible.
- If subsystem evaluation total equals 0, susceptibility to EME can not be determined.
- If subsystem evaluation total is less than 0 (negative), susceptibility to EME is not indicated.

Table 4. Step 2 in Completion of Subsystem Analysis Subtotal Worksheet

Subsystem: Small Lightweight GPS Receiver (SLGR)

SUBSYSTEM ANALYSIS WORKSHEET													
			FREQUENCY										
LINE NO.	ITEM	COMMENTS	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
1.	E^3 Criteria	Figure 5	2	2	2	2	2	2	2	2	5	6	6
2.	Platform Loss	No shield	0	0	0	0	0	0	0	0	0	0	0
3.	EME Inside Platform	Enter the sum of line 1 and line 2 here and also on line 10.	2	2	2	2	2	2	2	2	5	6	6
4.	Cable Shielding	Closely spaced	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
5.	Interface Attenuation	Power line	-3	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
6.	Cable Length	30 feet	-7	-5	-3	-2	-1	-1	-1	-1	-1	-1	-1
7.	Cable Subtotal	Add lines 4, 5, and 6 and enter the result here.	-12	-12	-10	-9	-8	-8	-8	-8	-8	-8	-8
8.	Case Shielding	single case, no untreated hole	-14	-13	-12	-11	-10	-9	-8	-7	-7	-6	-6
9.	Subsystem Shielding	Enter the larger of line 7 or line 8.											
10.	EME Inside Platform	(From line 3)	2	2	2	2	2	2	2	2	5	6	6
11.	Circuit Sensitivity	CMOS/RF	1	1	1	1	0	1	1	1	-1	-1	-1
12.	Weighting Factor	Minimal/low	1	1	1	1	1	1	2	2	2	2	2
13.	Subsystem Evaluation Total	Add lines 9, 10, 11, and 12. Enter the result here and on the system summary worksheet.											

Evaluation:

- If subsystem evaluation total is greater than +3, subsystem susceptibility to EME is likely.
- If subsystem evaluation total is between +1 and +3, susceptibility to EME is possible.
- If subsystem evaluation total equals 0, susceptibility to EME can not be determined.
- If subsystem evaluation total is less than 0 (negative), susceptibility to EME is not indicated.

Table 5. Final Step in Completion of Subsystem Analysis Worksheet

Subsystem: Small Lightweight GPS Receiver (SLGR)

SUBSYSTEM ANALYSIS WORKSHEET													
			FREQUENCY										
LINE NO.	ITEM	COMMENTS	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
1.	E^3 Criteria	Figure 5	2	2	2	2	2	2	2	2	5	6	6
2.	Platform Loss	No shield	0	0	0	0	0	0	0	0	0	0	0
3.	EME Inside Platform	Enter the sum of line 1 and line 2 here and also on line 10.	2	2	2	2	2	2	2	2	5	6	6
4.	Cable Shielding	Closely spaced	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
5.	Interface Attenuation	Power line	-3	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
6.	Cable Length	30 feet	-7	-5	-3	-2	-1	-1	-1	-1	-1	-1	-1
7.	Cable Subtotal	Add lines 4, 5, and 6 and enter the result here.	-12	-12	-10	-9	-8	-8	-3	-8	-8	-8	-8
8.	Case Shielding	single case, no untreated hole	-14	-13	-12	-11	-10	-9	-8	-7	-7	-6	-6
9.	Subsystem Shielding	Enter the larger of line 7 or line 8.	-12	-12	-10	-9	-8	-8	-8	-7	-7	-6	-6
10.	EME Inside Platform	(From line 3)	2	2	2	2	2	2	2	2	5	6	6
11.	Circuit Sensitivity	CMOS/RF	1	1	1	1	0	1	1	1	-1	-1	-1
12.	Weighting Factor	Minimal/low	1	1	1	1	1	1	2	2	2	2	2
13.	Subsystem Evaluation Total	Add lines 9, 10, 11, and 12. Enter the result here and on the system summary worksheet.	-8	-8	-6	-5	-5	-4	-3	-2	-1	1	1

Evaluation:

- If subsystem evaluation total is greater than +3, subsystem susceptibility to EME is likely.
- If subsystem evaluation total is between +1 and +3, susceptibility to EME is possible.
- If subsystem evaluation total equals 0, susceptibility to EME can not be determined.
- If subsystem evaluation total is less than 0 (negative), susceptibility to EME is not indicated.

cies. The table values corresponding to an EME value of 0 at each frequency are listed on the worksheet.

Line 4, Cable Shielding (see Attachment 2's Table 4). The cable shielding for the SLGR is represented by the item description of the closely spaced pair, as listed in the cable shielding table. These EME tables values are -2 at all the frequencies and are listed on the worksheet.

Line 5, Interface Attenuation (see Attachment 2's Table 5). The attenuation for the SLGR power line cable is the worst-case condition and is represented by the item description of the power line (60/400 Hz), 1 pole cable, in the interface attenuation table. The EME table values of -3 at 10 kHz and -5 at all other frequencies are listed on the worksheet.

Line 6, Cable Length (see Attachment 2's Table 6). The SLGR 30-foot cable length was selected under the item description column for the cable length table. The EME table values range from -7 at 10 kHz, up to -1 from 1 MHz to 10 GHz, and are listed on the worksheet.

Line 8, Case Shielding (see Attachment 2's Table 3). The E^3 protection that the SLGR case provides is represented in the item description column by the single case with no untreated holes. The EME table values range from -14 at 10 kHz to -6 at 10 GHz and are listed on the worksheet.

Line 11, Circuit Sensitivity (see Attachment 2's Table 7). The E3RB applied its judgment in deriving values for the EME values. They were arrived at by utilizing known parameters for SLGR based on the more stringent EME specification requirements. For example, under the item description column, the driving force for the parameters is the CMOS Logic (5 MHz), for frequencies below 10 MHz and the RF amplifier at the higher frequencies. The EME values range from 1 at 10 kHz to -1 at the higher frequencies. All of the EME values are listed in the worksheet.

Line 12, Weighting Factor (see Attachment 2's Table 8). The E3RB applied its judgment in assessing the weighting/safety factor. The assessment was based on known parameters of the SLGR and the more stringent EME specification requirements. In addition, the assessment considered criticality of subsystems, impact of failure, and available emitter data. In the item description column, a minimal weighting factor with an EME value of 1 to 30 MHz and a low weighting factor with an EME value of 2 at frequencies from 100 MHz to 10 GHz were selected and are listed on the worksheet.

5.2.2 Step 2

The second step of the SLGR subsystem analysis consists of adding the EME values for the categories according to instructions on the worksheet. For example, the EME inside the platform is determined by adding the E^3 criteria (line 1) to the platform loss (line 2) and placing the results on line 3 and line 10. The cable subtotal is determined by adding the cable shielding, interface attenuation, and cable length (lines 4, 5, and 6, respectively) and placing the results on line 7. The subtotal results are shown in Table 4.

5.2.3 Step 3

The final step in completing the subsystem analysis worksheet involves deciding whether or not the cable subtotal or case shielding is the weaker link and then totaling the subsystem evaluation. The cable subtotal (line 7) or case shielding (line 8), whichever value is greater, is entered on line 9 for the subsystem shielding. For example, at 10 kHz, the cable subtotal is -12 and the case shielding is -14; therefore, -12 (greater value) is entered on line 9. The subsystem evaluation on line 13 is a total of lines 9 through 12. The results are shown in Table 5 and Attachment 3's Table 4.

6 EME TRENDS and IMPLICATIONS

For future E^3 projects, constantly changing battlefield scenarios and system threats have to be analyzed. In addition, new emitters and jammers and their possible impact on existing Army systems must be evaluated as data are made available. In order to meet present and projected threats, careful attention should be directed toward the scope and direction of EMC activities and new trends for interference-control requirements. The effects of downsizing systems and associated integration of platforms must also be addressed.

External threats to Army systems (as well as friendly offensive RF capabilities, tactical and fixed radars, new emitters, and co-site emitters) have to be analyzed as part of the EME in order to establish the E^3 criteria. Accordingly, the model for battlefield emitters, shown in Figures 1 through 5, must be updated to include all relevant emitters. A modified profile of the emitters' field strength must be used, in conjunction with the EME values, to establish the E^3 criteria for the new scenario. When assessing new or relocated emitters, threats, and jammers, it is important to critique the potential impact on the system/equipment, since additional studies or analyses may be required. This situation applies, for example, to the NDI program, since it did not include E^3 testing prior to production and ongoing studies would be required to evaluate the threat from in-band signals.

The electromagnetic characteristics of the subsystems of Army systems should also be considered as part of the new EMC activities in order to ensure EMC between the system and external environment. Intrasystem EMC must also be achieved so that each subsystem and equipment may operate without performance degradation, with respect to the mission requirements. Trends in EMC indicate that computer modeling may now be obtained from antenna to antenna. For each subsystem/equipment the specific requirements of MIL-STD-461 and MIL-STD-462, which include emission and susceptibility characteristics, must be met.

7 CONCLUSIONS

This report summarizes the EME and E^3 criteria relevant to CECOM equipment. As a result of researching present and projected battlefield scenarios that may constitute potential malfunction or damage to the system/equipment, a model for the EME and E^3 criteria was developed. Based on analysis results, Army systems that are the responsibility of CECOM are expected to be able to meet E^3 criteria; however, some equipment items have potential frequency interference problems beyond 1 GHz. Additional analyses and/or testing will be necessary for these items.

Constantly evolving battlefield scenarios with projected threats and complex automated subsystems require ongoing efforts to evaluate E^3 criteria and analyze electromagnetic phenomena that may constitute potential causes of malfunction or damage to the system/equipment. Many currently fielded systems must be reassessed when they include workstations, downsized switches, or remote equipment. Equipment/subsystems that underwent previous EMI testing and were modified may not comply with the radiated susceptibility requirements of MIL-STD-461, and equipment/subsystems previously evaluated in accordance with MIL-STD-462 may have broadband and narrowband emissions in excess of the specified limits. Potential susceptibilities associated with cables may also be evaluated and improved with fiber-optic cables. Any of these possibilities may require additional analysis/tests and/or corrective action.

Future battlefield scenarios should be well planned. Emitters and their probable locations should be known in detail prior to a confrontation. It is also important to know or estimate which emitters may be Blue and which Red, depending on the geopolitical situation. In addition, the characteristics and locations of Gray (commercial) emitters should also be determined so that they are not mistaken for hostile emitters or present unnecessary risks to the systems.

The E^3 program goal is to ensure that Army equipment completes its mission in its EME. With the wide use of high-power RF transmitters, the threat posed by the emitters is increased, and steps must be taken to establish an integrated E^3 program plan. A range of different threats and/or interference problems must be considered for potential impact on Army systems and for establishing the minimum level of protection necessary for the system to successfully perform its mission. To accomplish this goal within the 11 E3RBs requires that a CECOM working group or EMI advisory board be established as a team/point of contact to carefully monitor all EME activities, provide coordination with the E3RBs, review ongoing tests/analysis, and provide technical expertise for EMI working group meetings (MIL-STD-461, MIL-STD-462), EMC symposiums, etc.

8 ACRONYMS

AAE	Army Acquisition Executive
ADCCS	Air Defense Command and Control System
ADDS	Army Data Distribution System
AFATDS	Advanced Field Artillery Tactical Data System
AMC	Army Materiel Command
AMSAA	Army Materiel Systems Acquisition Activity
ASAS	All Source Analysis System
C2SID	Command, Control and Systems Integration Directorate
CCS	Command and Control Systems
CECOM	U.S. Army Communications-Electronics Command
COMM	Communications Systems
CSSCS	Combat Service Support Control System
DA	Department of the Army
DOD	Department of Defense
E^3	Electromagnetic environmental effects
E3RB	Electromagnetic Environmental Effects Review Board
ECAC	Electromagnetic Compatibility Analysis Center
EMC	Electromagnetic compatibility
EME	Electromagnetic environment
EMI	Electromagnetic interference
EMP	Electromagnetic pulse
EPLRS	Enhanced Position Location Reporting System
FAADC2I	Forward Area Air Defense Command, Control and Intelligence
FATDS	Field Artillery Tactical Data System

FCC	Federal Communications Commission
GPS	Global Positioning System
IEW	Intelligence and Electronic Warfare
JSTARS	Joint Surveillance Target Attack Radar System
JTIDS	Joint Tactical Information Distribution System
MCS	Maneuver Control System
MSE	Mobile Subscriber Equipment
MSRT	Mobile Subscriber Radiotelephone Terminal
NDI	Nondevelopmental item
OPTADS	Operations Tactical Data Systems
PEO	Program Executive Office(r)
PLGR	Precision Lightweight GPS Receiver
PM	Project manager
RDEC	Research, Development and Engineering Center (CECOM)
RF	Radio frequency
RFI	Radio frequency interference
S&TCD	Space and Terrestrial Communications Directorate
SINCGARS	Single Channel Ground and Airborne Radio System
SLGR	Small Lightweight GPS Receiver
TQM	Total quality management
USAEPG	U.S. Army Electronic Proving Ground
VDT	Video display terminal

Attachment 1

Army E^3 Program: A Process Focused on Teaming

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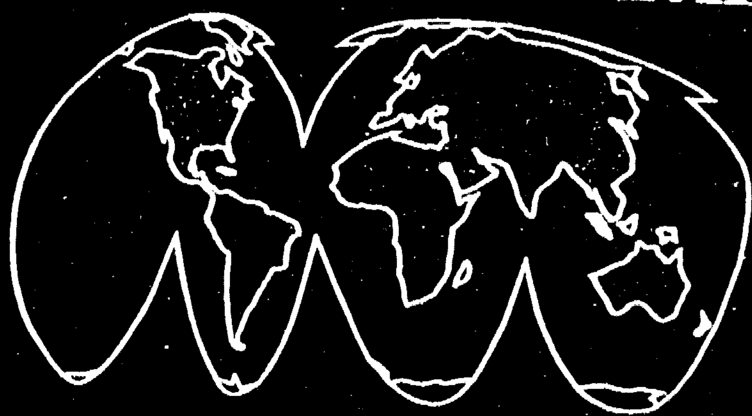

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ARMY E3 PROGRAM:
A PROCESS FOCUSED ON TEAMING

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Abstract

This paper highlights the history of the Army electromagnetic environmental effects (E3) program, including the management approaches that were used to execute the program. Weaknesses in this process resulted in very serious system deficiencies that have been difficult and expensive to correct. The paper reviews the Department of the Army (DA) policy changes that have been implemented to improve the E3 program. Key changes include the establishment of E3 Review Boards (E3RBs) as advisory teams designed to support acquisition managers' awareness of the electromagnetic environment in which systems must survive. The teams' main functions are to define the environment, establish impact, and propose solutions for management decision. The paper highlights the power of the Total Quality Management (TQM)-based working group process with specific case studies worked by E3 boards and examines benefits that the program has achieved while operating in a world of diminishing resources. The paper concludes with a status summary and a look at the future of the E3 program.

1. Army E3 Focused on Teaming

DA E3 policy was refocused by the Army Acquisition Executive (AAE) in Policy Memorandum 91-3 of 22 January 1991. This memorandum provided new policy guidance on the E3 program, stating the program's goal to identify and quantify system limitations when operating in its expected electromagnetic environment (EME). The AAE memorandum identified the major players as project managers and other program sponsors, user representatives, and technical matrix organizations supporting programs. The new Army policy mandated use of E3RBs to team all the program acquisition disciplines in advisory groups designed to support E3 decisions made by program managers regarding complex EMEs such as illustrated in Figure 1.

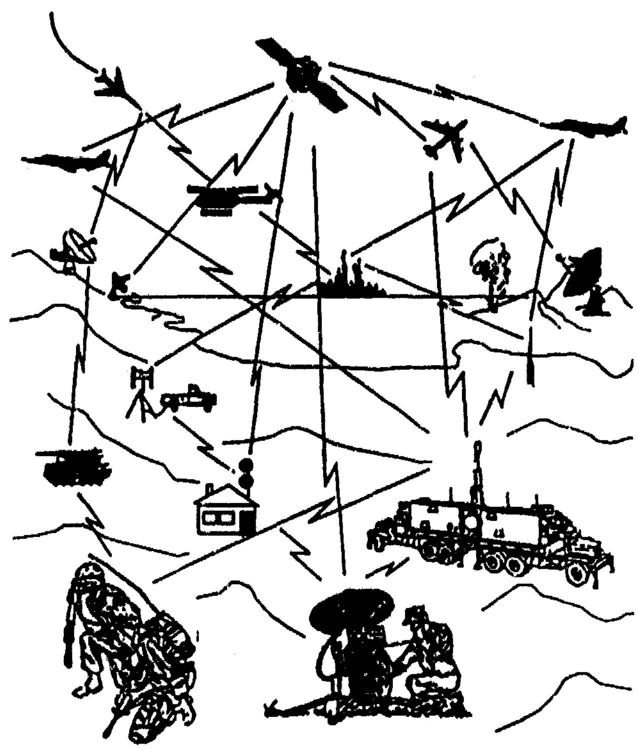

Figure 1. Complex Electromagnetic Environment

2. History

The E3 program dates back to the early days of electronic systems on the battlefield. As early as the 1930s and 1940s, interference from friendly as well as hostile forces was of great importance to tactical communications.

During this period, the exploration of higher frequency bands was evolving. By the early 1940s, use of a portion of the UHF spectrum (200 to 600

MHz) was well established. World War II was accompanied by additional expansion into the microwave bands above 1 GHz. In parallel with this trend, continued improvement in technology resulted in increased power from radio-frequency (RF) sources and higher sensitivity of receiver systems.

During the pre-World War II Louisiana Exercise, vehicular interference was so intense that communications were disrupted. Then-Colonel Dwight D. Eisenhower was in charge of these maneuvers. He insisted that something be done to reduce this interference. Much of the work to resolve this problem was completed at Fort Monmouth. This work included early large-scale computer simulation of interference under PROJECT MONMOUTH.

In July 1960, concerns arising from the PROJECT MONMOUTH studies of the increasing impact of radio-frequency interference (RFI) on military operations prompted the Department of Defense (DoD) to initiate a program to ensure electromagnetic compatibility (EMC) during the conceptual, design, acquisition, and operational life-cycle phases of all military communications-electronics (C-E) equipment. subsystems, and systems. The program provided for the establishment of a center to analyze the EMC aspects of developing C-E systems and a database for support of analysis efforts. DoD Directive 3222.3 assigned responsibility for EMC standards and specifications to the Secretary of the Navy, for EMC measurement techniques and instrumentation to the Secretary of the Army, and for EMC analysis capabilities and use of the EMC database to the Secretary of the Air Force. The Air Force was, therefore, designated the administrative agency for the joint DoD Electromagnetic Compatibility Analysis Center (ECAC).

More recently, commencing with the Vietnam conflict, the sophistication and sensitivity of electronic battlefield systems to both friendly and hostile sources of interference became even more significant. Jamming and propagation problems became major factors in the determination of communications systems performance, and cosite interference became a major source of interference.

During the 1980s, battlefield automation and system complexity became significant E3 factors on the global battlefield. Further, system sensitivity to outside disturbances has multiplied tenfold with the introduction of integrated circuit technology and improved solid state amplification in the GHz bands.

Hardening these systems to the EME has been difficult and expensive. The advent of non-developmental items (NDIs) and their compressed acquisition approaches during the mid-1980s added a level of uncertainty to adequately defining the EME in which a system must perform. Program officers and their staffs were focused on fielding new products quickly at reduced cost. Some NDI technology provided only the level of EME protection inherent in existing product design. Hardware acquired through the NDI process was selected based on existing capabilities with little regard to the impact that other battlefield systems might have on performance. Emerging problems with complexity and battlefield automation were generally not considered. The current geopolitical situation that potentially places former Red emitters on the same side of the battlefield as the friendly Blues was certainly not considered by acquisition staffs prior to 1991.

3. A New Way of Doing Business

The new policy implemented in 1991 is designed to focus on these weaknesses through the use of integrated teams of Army acquisition staff composed of project managers, their technical matrix staff, and the combat developers. These teams are the E3RBs. They are designed to act as advisory bodies to support project decisions that are driven by the electromagnetic environments in which the system must survive. Key responsibilities of the boards are defining the environment, determining its impact on the system, and designing and taking corrective action to reduce system vulnerability. Solutions may take the form of design changes, operational workarounds, or avoidance when all else has been ruled impractical or impossible.

4. CECOM Program

The U.S. Army Communications-Electronics Command (CECOM) implementation of the E3 program has been focused on matrix support to Level I project managers in the Program Executive Offices (PEOs) for Communications Systems (COMM), Command and Control Systems, and Intelligence and Electronic Warfare (IEW). Within the CECOM Research, Development and Engineering Center (RDEC), a focal point for all E3 issues was identified. This focal point is the Command, Control and Communications (C3) Engineering Division (C3ED) within the C3 Systems Directorate (C3SD). The responsibility for chairing the E3RBs was assigned to the lead technical activity supporting the project managers for the Level 1 systems to be covered. Senior-level technical staff from the RDEC directorates were assigned to boards supporting the eleven major programs to be covered by December 1991. These boards are listed in Table 1.

Table 1. CECOM E3 Boards

Board Chairman	Organization (see List of Acronyms)	PM/PEO
C3SD	EPLRS	COMM
	JTIDS	COMM
C3SD	GPS	COMM
C3SD	MSE	COMM
C3SD	SINCGARS	COMM
C3SD	AFATDS	CCS
	ASAS	CCS
	CSSCS	CCS
	FAADC2I	CCS
	MCS	CCS
EW/RSTA	JSTARS	IEW

Each of these boards has been operated as an advisory group to the program manager. The boards use the tools of TQM to develop the environment in which the system must survive, work the system vulnerabilities, and develop action plans for their respective PMs. This process flow is depicted in Figure 2. Generally, all of the boards have had regular meetings and have at least published an initial report on significant results. Some of the interesting efforts to date include:

- Predicting levels of vulnerability.
  - Informing users of operational workarounds.
- Supporting 461/462 Standards tailored for NDI acquisitions.
- Determining impacts on collocated systems.
- Integrating platforms.
- Focusing on the impact of battlefield automation.

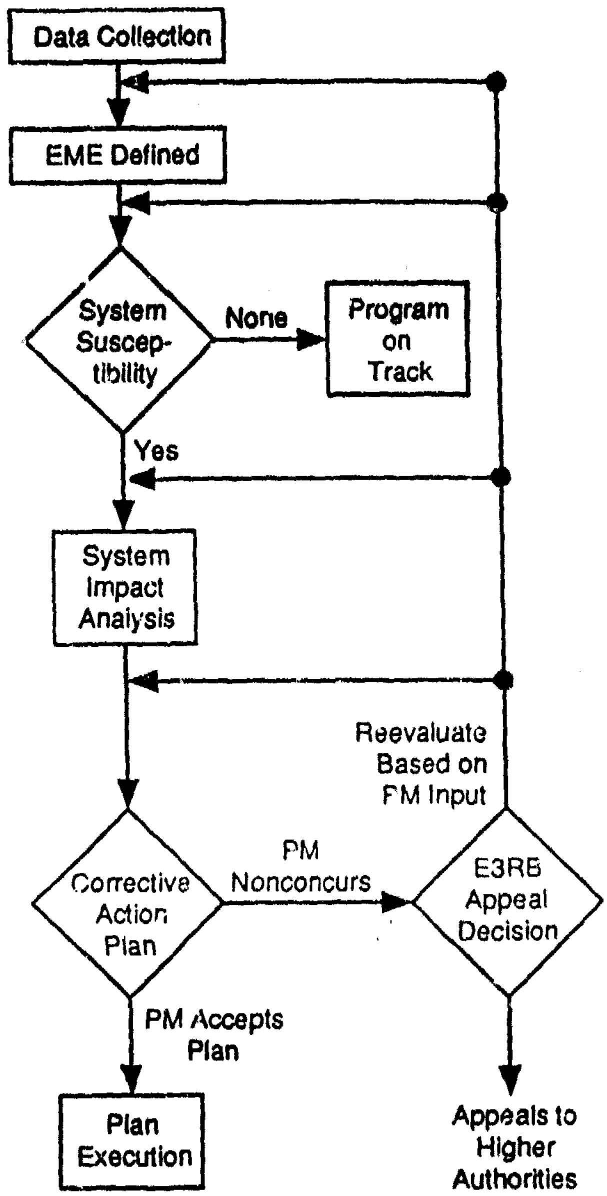

Figure 2. E3RB Process

As a result of the TEAMING and sharing of knowledge/skills among the key players, several program weaknesses were uncovered. All of these issues have been shared through a CECOM working group chaired by the CECOM command representative.

The CECOM boards address issues that include:

- In-band communication engineering analysis.
- Battlefield automation.
- Propagation impact.
- EMI budgeting.

5. Army Materiel Command Working Group

An Army Materiel Command (AMC) working group shares ideas among Army commodity managers. Issues concerning AMC and DA have been presented at the AMC-based Army E3 Board.

In some cases, these issues were solved by the individual boards; in others, issues have been elevated to the AMC group to be worked by representatives of all of the major subordinate commands. Major issues at the AMC level include:

- Environment determination and maintenance.
- Maintenance of E3 awareness for all career disciplines.
- Funding.
- Process for lightning/nuclear.

6. E3 Future

The future of the E3 program remains bright. Even with the significant budgetary constraints all DoD staff are facing, this program has the visibility to survive. More important, the thrust of using the E3RB approach has achieved measurable results. Effort for the major systems will continue with the focus on emerging battlefield scenarios, platform integration, and battlefield automated systems.

During the first year of the process, several new PM-managed boards have been chartered in the space and intelligence/electronic warfare worlds. This expansion will continue.

A CECOM Level II/III program for smaller systems and components started in 1992. This process is tailored to the large number of systems and components that CECOM provides to the rest of the Army. These E3RBs are designed to be commodity oriented. The first Level II/III E3RB is supporting CECOM's aviation-related products. The overall process for Level II/III systems has been developed by a process action team made up of representatives from the directorates that are part of the process. It is the same process used on major system programs but is focused more on platform integration. Major team players include the project office, users, and technical staff.

To summarize, the Army has had an E3 program for many years. AAE Memorandum 91-3 initiated a recent DA refocus. CECOM implemented the program for major systems during 1991 and is currently implementing the program for all its systems during 1992. The key to continued success will be measurable results that save Army dollars. To date the program track record is excellent.

List of Acronyms in Table 1

AFATDS	Advanced Field Artillery Tactical Data System
ASAS	All Source Analysis System
C3SD	Command, Control and Communications Systems Directorate
CCS	Command and Control Systems
COMM	Communications Systems
CSSCS	Combat Service/Support Control System
EW/RSTA	Electronic Warfare/Reconnaissance, Surveillance, Target Acquisition
EPLRS	Enhanced Position Location Reporting System
FAADC2I	Forward Area Air Defense Command, Control, and Intelligence
GPS	Global Positioning System
IEW	Intelligence and Electronic Warfare
JSTARS	Joint Surveillance, Target Acquisition and Reconnaissance System
JTIDS	Joint Tactical Information Distribution System
MCS	Maneuver Control System
MSE	Mobile Subscriber Equipment
PEO	Program Executive Office(r)
PM	Project Manager
SINCGARS	Single Channel Ground and Airborne Radio System

Biographies

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Attachment 2

E^3 Assessment Methodology

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3) ASSESSMENT METHODOLOGY

SEPTEMBER 1991

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E^3 ASSESSMENT METHODOLOGY
EXECUTIVE SUMMARY

This methodology provides a critical tool for Program Managers (PMs) to comply with Army Acquisition Executive (AAE) Policy Memorandum 91-3, Army Electromagnetic Environmental Effects (E^3) Program Implementation (paragraph 6.2), for major systems. It enables the PM to conduct a first-order E^3 assessment of a system by analyzing its component subsystems prior to extensive E^3 testing. It is not a substitute, nor does it eliminate the necessity, for testing and independent evaluation. The techniques developed here have limitations, defined in caveats appearing in the main text and summarized in appendix D. It should be noted that transient time domain effects of lightning, electrostatic discharge, and electromagnetic pulse are not covered and must be considered independently. Also note that "effects," as used here, means the threshold or onset of effects due to the electromagnetic environment. Use of this assessment methodology is the option of the PM.

The methodology consists of four phases: data collection; subsystem analysis; impact evaluation; and action by the PM in response to predicted impact. The subsystem analysis phase is the central focus of the methodology, utilizing acquired data and system design information. The results provide an estimate of potential E^3 susceptibilities and the frequency bands in which they occur. For each potential subsystem susceptibility identified, the PM evaluates the impact on overall system safety and mission accomplishment. The impact of the identified susceptibilities provides guidance to the PM, allowing informed decisions for allocation of technical and funding resources. Any potential susceptibility that could have unacceptable impact represents a major E^3 problem requiring prompt action by the PM. That action can take the form of a more detailed analysis, follow-on E^3 testing, or immediate corrective action. If the results of a subsystem analysis and impact evaluation do not indicate that major E^3 problems are likely, exceptional action by the PM is not necessary, and the programmed E^3 test and evaluation should proceed on schedule.

E^3 ASSESSMENT METHODOLOGY

SECTION 1. INTRODUCTION

1.1 GENERAL

Army Acquisition Executive (AAE) Policy Memorandum 91-3, dated 22 January 1991 (appendix A), establishes policy and implementation guidance for the Army Electromagnetic Environmental Effects (E^3) Program. It applies to all systems, subsystems, component parts, and support equipment acquired under any acquisition strategy from all Army mission areas and is being implemented for systems still in acquisition, as well as for fielded systems. The goal of the E^3 program is to ensure that Army materiel accomplishes its intended mission in the electromagnetic environment (EME) present in times of both peace and war. The methodology outlined in this document was developed as a tool to help PMs meet the requirements of AAE Policy Memorandum 91-3 for acquisition category (ACAT) I and II programs whose milestone II or equivalent decision occurred prior to 31 December 1990. These requirements include:

a. Establishing the system's expected EME and its E^3 criteria. E^3 criteria, as explained in AAE Policy Memorandum 91-3, is the subset of the system's EME that defines a baseline level of protection.

b. Determining potential safety hazards or mission degradation caused by the established E^3 criteria.

c. Developing a short-term plan to quantify and address the potential safety hazards and/or mission degradation.

d. Establishing a long-term plan to conduct further system evaluation and/or testing based upon the E^3 criteria and to incorporate E^3 protection into the life cycle control process.

1.2 PURPOSE

The methodology described in this document provides the PM with an analytical procedure for conducting first-order E^3 assessments of systems beyond milestone II in accordance with AAE Policy Memorandum 91-3. Its use is optional and is intended to meet the short-term requirements of AAE Policy Memo 91-3. PMs do not need to use this process if the E^3 requirements board determines that: (1) the system has already been tested to an EME that is equivalent to or greater than its E^3 criteria; or (2) an acceptable alternative methodology is being used. Given that the system's EME and E^3 criteria have been defined [requirement (a), paragraph 1.1, above], this methodology enables first-order E^3 assessments to be conducted by analyzing existing system data without additional up-front testing. The resultant assessment will help identify potential subsystem EME susceptibilities. This information will allow the PM, in conjunction with the E^3 requirements board, to comply with AAE Policy Memorandum 91-3 requirements (b), (c), and (d), listed in paragraph 1.1, above.

This methodology is a useful simplification of a very complex process. It is not meant as a substitute for normal E^3 testing, and the resulting E^3 assessment will not be as precise as one that results from extensive testing. Program managers must remember that, as a first-order analysis, this technique is designed to provide indications of major E^3 problems. If results indicate that major problems do not exist, immediate action is not necessary, and the PM should continue his E^3 testing program as planned. While this technique is limited, it can be used effectively in conjunction with a system's test and evaluation program. Its value lies in its ability to give the PM enough information to determine his near-term needs for additional resources for further analysis, testing, or corrective action.

It is anticipated that the PM will use internal resources when applying this methodology. Ideally, the individual who conducts the assessment should have detailed knowledge of system design as well as a background in, and an understanding of, electronics and electromagnetic theory. While this kind of background is not essential for this methodology, it will be very helpful, particularly during the analysis phase, where engineering judgements may be required.

1.3 OVERVIEW

This E^3 assessment methodology, as portrayed in Figure 1, can be divided into four phases: data collection; subsystem analysis; impact evaluation; and PM action. The process allows an entire system to be examined by analyzing its individual subsystems. The assumption is made that, if a subsystem shows a susceptibility to the EME, it is a susceptibility of the overall system. It is assumed that there are no synergisms or resonant effects. The subsystem analyses identify those subsystems with potential susceptibilities to the EME defined by the E^3 criteria, showing where system EME susceptibilities are likely to occur.

Within this process, a subsystem can be viewed as a collection of functionally related circuits that are physically located in proximity to one another. It is usually contained within a continuous case or shell, which provides a degree of physical protection, as well as E^3 protection. To be considered a subsystem for purposes of this methodology, the functionally related circuits should have comparable input filtering, cable shielding, and case shielding. For example, a case may contain both a power supply and high speed digital circuits. The power supply, which has an unshielded power cord and an input filter, would be considered a different subsystem than the digital circuits, which have shielded cables and no input filter (or one of a substantially different design from that of the power supply). On the other hand, one subsystem can be composed of several black boxes. A separate multicomponent unit, whose case becomes part of another unit's case (such as a battery pack), would be analyzed together as one subsystem, as long as the units maintain comparable input filtering, cable, and case shielding. Cables leading to or from a subsystem are considered part of the subsystem and are analyzed with the subsystem to which they are connected.

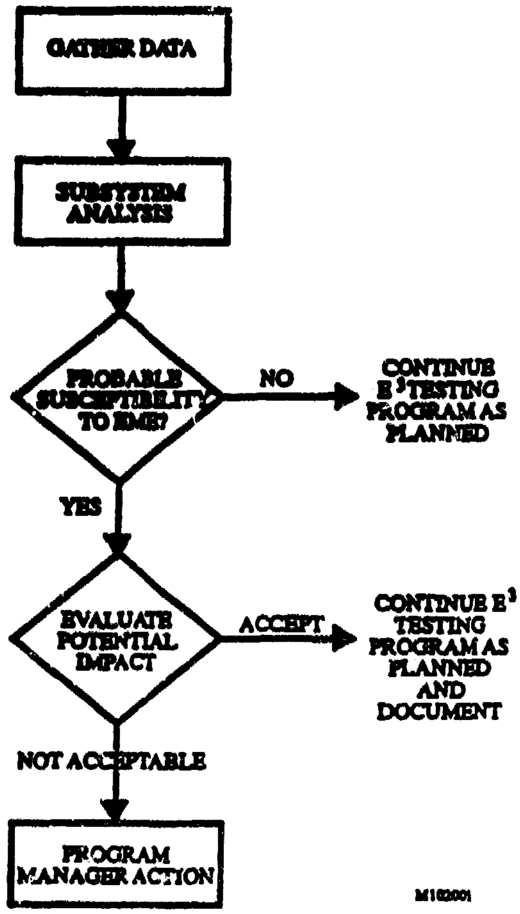

Figure 1. E^3 Assessment Methodology

The first phase of the process is the collection of data. It is a critical phase, as the analysis of a subsystem can be only as detailed and precise as the data that describes it. Section 2 discusses the data collection phase.

The next phase, subsystem analysis, is the crux of the E^3 assessment process. The analysis phase focuses on an evaluation of the effect of the system's E^3 criteria on the subsystem (e.g., cable and case shielding, cable interface, and circuit design). The analysis phase also considers the type of platform upon which the system is mounted (e.g., vehicle, tank, aircraft) and the E^3 protection it provides. Section 3 describes the analysis phase.

If the results of the analysis phase indicate that a subsystem has potential EME susceptibilities based upon the system's E^3 criteria, an evaluation of its impact is conducted. The impact evaluation phase assesses potential mission degradation and safety implications. If the impact is determined to be unacceptable, the susceptibility is deemed a vulnerability, and immediate action is required. The type and extent of that action will be determined by the E^3 requirements board and recommended to the PM. Action could take the form of a more detailed analysis, follow-on E^3 testing, or immediate corrective action. Cost, time, and the severity of the potential problem will be key considerations in this decision making process. Section 4 discusses the impact evaluation and the PM action phases.

SECTION 2. DATA COLLECTION

System and subsystem data must be collected prior to performing an analysis of the system's component subsystems. Data elements are described in paragraphs 2.1 through 2.4 below. The availability of data at the desired level of detail will directly affect the quality of the E^3 analysis. Where data elements are not available, prudent assumptions must be made based upon the information that is available and the engineering judgement and recommendation of the individual conducting the assessment.

2.1 SYSTEM AND SUBSYSTEM SPECIFICATIONS AND DRAWINGS

Data required from system/subsystem specifications and drawings focus on parametric data, E^3 requirements, and the E^3 protective measures included in the design to comply with those requirements. Parametric data include frequencies, bandwidths, sensitivities, voltage and power levels, and any other data related to the system's performance in the EME defined by the E^3 criteria. Data on system E^3 requirements and E^3 protective measures include information on shielding, bonding, grounding, filtering, circuit, cable, and interface design. Shielding information includes the E^3 protection provided by the subsystem case, as well as the protection provided by its external cables. It is also important to have complete information on all the various configurations in which a system can operate, as well as the various kinds of platforms or vehicles from which the system is designed to operate.

To enable the PM to collect the specific system or subsystem data needed, some key questions must be answered:

a. Subsystem Case: In determining the shielding effectiveness of the case, it is important to know the material from which it is made. Is it metal? If not, has a shielding coating been applied? Are metal seams cleaned to bare metal before assembly? Are seams fastened with closely-spaced screws or rivets, welded, or rolled? Are ventilation holes treated with shielding material? What are the sizes of any untreated holes? Are access covers provided with electromagnetic interference (EMI) gaskets, or is there metal-to-metal contact?

b. Subsystem Cables: Cabling includes those wires (e.g., control, video, audio) that interface with other systems or subsystems either inside or outside of the platform (e.g., antennas, input, output, display devices). For each cable connected to a subsystem, the following information is needed:

- Shielding: What type of shielding does the cable employ (e.g., single coax, twisted pair, solid conduit)? Have the cable shields been installed properly (i.e., 360 degree termination to connector backshells)?

- Interface Attenuation: What type of treatment (e.g., filter, feed-through capacitor) is applied to the cable at its point of entry into the subsystem?

- Length: How long (in terms of feet) is the exposed section of each cable?

c. **Circuit Sensitivity:** What type of circuits are used in the subsystem (e.g., audio, video, radio frequency (RF), intermediate frequency (IF), or traveling wave tube (TWT) amplifiers, comparators, drivers, clocks, relays, power supplies)? What type of logic is used [e.g., transistor-transistor logic (TTL), complimentary metal oxide semiconductor (CMOS)]?

d. **Platform:** In what type of vehicle/platform will the system be installed? For example, is it a heavily armored vehicle, a metal truck, a vehicle with an open cab, or a steel framed building?

2.2 EME AND E^3 CRITERIA

A critical element of the data required to conduct an E^3 assessment of a system is the EME to which the system is expected to be exposed. Based on this EME, the PM will define the system's E^3 criteria. The E^3 criteria represents the EME for which a system should be designed and defines the minimum level of protection necessary for the system to successfully perform its mission in the intended operating environment. The E^3 criteria should include the following, as appropriate: frequency, field strength, power density, pulse characteristics, and modulation information.

2.3 SYSTEM MISSIONS AND FUNCTIONS

System missions are crucial to the identification of the EME in which a system will be expected to operate. Mission priorities and criticality are also important and will be a key element when assessing the impact of any potential EME susceptibilities. The impact evaluation process also will require data on the system's operational and performance characteristics, including effectiveness thresholds.

2.4 KNOWN E^3-RELATED DATA

Included in this category, particularly for systems already fielded, is the identification of known or suspected safety or operational problems that may be attributable to E^3. Other elements of known E^3-related data include the results of any system or subsystem E^3 tests and E^3-related waivers, either planned, requested, or approved. All of this information will help pinpoint susceptibilities to the EME defined by the E^3 criteria. It will also be useful to review system operator and maintenance publications. From the E^3 life cycle control perspective, a review of these publications will help determine: (1) the degree to which desired E^3 protective measures have been incorporated into routine operator and maintenance publications; and (2) where additional E^3 protection needs to be included.

SECTION 3. SUBSYSTEM ANALYSIS

3.1 PURPOSE

During the subsystem analysis phase, E^3 protective measures included in the design will be evaluated in relation to the system's E^3 criteria to determine whether potential susceptibilities to the EME exist. Eight separate categories will be evaluated: E^3 criteria; platform loss; case shielding; cable shielding; interface attenuation; cable length; circuit sensitivity; and a weighting factor. Each of these categories is defined and discussed in detail in paragraph 3.2. Relative values of amplitude, sensitivity, or protection, as appropriate, will be determined for each of the eight categories. Tables 1 through 8 will be used to determine these values as a function of frequency. The specific frequencies used in these tables actually represent the center of a range of frequencies, as indicated below:

Center Frequency	Frequency Range
10 kHz	1-32 kHz
100 kHz	32-320 kHz
1 MHz	.32-1.7 MHz
3 MHz	1.7-5.8 MHz
10 MHz	5.8-17 MHz
30 MHz	17-58 MHz
100 MHz	58-170 MHz
300 MHz	170-580 MHz
1 GHz	.58-1.7 GHz
3 GHz	1.7-5.8 GHz
10 GHz	5.8-17 GHz

The values in Tables 2 through 7 were developed by establishing a baseline level (0 dB) susceptibility for comparison purposes and then changing each parameter while keeping all others constant. (Table 8, Weighting Factor, is constant with respect to frequency). The resulting differences in susceptibility from the baseline for each frequency band were then noted and assigned to that frequency band within the appropriate table. A more detailed discussion is presented at appendix E. The combination of the values chosen from the tables will provide the initial assessment of a subsystem's potential susceptibility to the E^3 criteria. The subsystem analysis not only will provide indications of the likelihood of EME susceptibility, but also will pinpoint the frequency bands in which those susceptibilities exist. This analysis is not intended to be a rigorous mathematical procedure, but it will give the PM an indication of potential susceptibilities and will allow him to make the appropriate management decisions regarding follow-on actions.

3.2 PROCEDURE

The eight categories to be evaluated are discussed below in paragraphs 3.2.1 through 3.2.8, with specific examples for each category depicted in Tables 1 through 8. Using the guidelines discussed below for each category, the individual performing the analysis will evaluate each category using the appropriate subsystem data. The values for each of the 11 frequency bands are taken from each of the tables and recorded on the corresponding line in the subsystem analysis worksheet (appendix B). After all categories for the subsystem have been evaluated and the appropriate entries made in appendix B, the EME inside the platform and the subsystem shielding effectiveness are determined as described in paragraph 3.2.9. The respective values for subsystem shielding, EME inside the platform, circuit sensitivity, and the weighting factor are then added to determine the overall subsystem evaluation and its susceptibility to the E^3 criteria. Intermediate values (whole numbers) between those listed in the tables may be chosen if, in the judgment of the individual conducting the analysis, the actual situation for that subsystem falls somewhere between the values indicated. When the analysis of all appropriate subsystems for a system has been completed, the evaluation total for each subsystem is entered on the system summary worksheet (appendix C). Systems with more than one operational configuration (e.g., a different platform or operation from a remote unit) may require that assessments be conducted for each configuration.

3.2.1 E^3 Criteria

A system's E^3 criteria must be defined before the analysis phase begins. The better defined the E^3 criteria is, the more valid is the assessment that will be obtained. If the system's E^3 criteria is known in terms of field strength versus frequency, Table 1 can be used to determine the EME values for the E^3 criteria. For each increase of 10 dBV/m in field strength, the EME value increases by 1. If the field strength value falls in between two EME values, the next highest EME value should be chosen, as only whole numbers are used to represent EME values. Once the EME values for the E^3 criteria are determined, they should be entered in the appropriate column of line 1 in appendix B.

Table 1: EME Values vs. Field Strength

Field Strength				EME Value
V/m	dBuV/m	dBV/m	*mW/cm²	
1	120	0	.000265	0
3.2	130	10	.00265	1
10	140	20	.0265	2
32	150	30	.265	3
100	160	40	2.65	4
320	170	50	26.5	5
1000	180	60	265	6
3200	190	70	2650	7
10000	200	80	26500	8
32000	210	90	2.65×10^5	9
100k	220	100	2.65×10^6	10
320k	230	110	2.65×10^7	11
1M	240	120	2.65×10^8	12
3.2M	250	130	2.65×10^9	13

*If given in W/m², mW/cm² = W/m² x 10

3.2.2 Platform Loss

Platform loss is a measure of the degree to which the platform carrying the system will provide a reduction of the effect of EME. The platform loss listings provided in Table 2 are representative of some of the actual platforms used and indicate their relative capability to protect the system from the EME defined by its E^3 criteria. A communications van, for example, can be considered either a minimal shield room or a steel room with untreated seams, depending on the degree of shielding used. A minimal shield room includes: seams sealed with conductive material, screened openings, incoming wires that are shielded or filtered, and metal doors with conductive gaskets or finger stock.

Table 2. Platform Loss

Item Description	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
HIGH QUALITY SHIELD ROOM	-14	-14	-14	-14	-14	-14	-13	-13	-12	-12	-12
TWO LAYER BRONZE SCREEN ROOM	-12	-12	-12	-12	-12	-12	-12	-12	-12	-8	-5
MISSILE WITH 1" APERTURE	-11	-9	-7	-6	-5	-4	-3	-2	-1	-1	-1
MISSILE WITH 3" APERTURE	-10	-8	-6	-5	-4	-3	-2	-1	-1	-1	-1
MISSILE WITH 10" APERTURE	-9	-7	-5	-4	-3	-2	-1	-1	-1	-1	-1
MINIMAL SHIELD ROOM	-9	-8	-7	-6	-5	-5	-5	-4	-4	-3	-3
TANK OR ARMORED VEHICLE	-9	-7	-5	-4	-3	-2	-1	-1	-1	-1	-1
CAR OR TRUCK (ENCLOSED-METAL SKIN)	-8	-6	-4	-3	-2	-1	-1	-1	-1	-1	-1
STEEL ROOM (UNTREATED SEAMS)	-8	-6	-4	-3	-2	-1	-1	-1	-2	-2	-3
CREW CAB WITH LARGE PLASTIC WINDOW	-8	-6	-4	-3	-2	-1	0	0	0	0	0
AIRCRAFT (MILITARY)	-7	-5	-3	-2	-1	0	-1	-1	-1	-1	-1
STEEL FRAME BUILDING	-5	-5	-3	-2	-1	0	-1	-1	-1	-2	-2
MANPACK (NO SHIELDING)	0	0	0	0	0	0	0	0	0	0	0

In order to gain the full E^3 protection provided by a platform, two basic assumptions must be made. The first assumption is that the entire subsystem, including cables, is contained within the platform. If this is not the case, the subsystem loses the protection provided by the platform. The choice of platform is then dependent upon the protection, if any, provided to that part of the subsystem not contained within the platform. For example, if a subsystem in a communications shelter on the back of a truck has a cable that leads to the cab of the truck, the subsystem will not get the protection provided by the shelter, but will get the protection provided by the "crew cab." If, instead, the cable led to a remote unit in the open, no platform shielding will be provided.

The second assumption made is that the subsystem case is bonded properly to the platform. If this is not the situation, it will negate the protection provided by the platform, and additional leakage would occur in the cables. To account for this, increase the cable length by one increment in the cable length category (e.g., from 3 ft. to 10 ft., or from 30 ft. to 100 ft.). This will allow for the lack of proper case-to-platform bonding.

Many systems are designed for use on several different platforms and will require that assessments be conducted for each variant. For example, a communications system may operate in a manpack mode, a wheeled vehicle, aircraft, or an armored vehicle, each providing a different degree of platform protection. The system's EME and E^3 criteria also may be different, and the resultant assessments will likely be different as well. These different assessments will provide the PM with valuable information regarding performance limitations in specific configurations and/or environments. Based on the configuration being evaluated, the appropriate platform is chosen, and the values from Table 2 are entered on line 2 of appendix B.

3.2.3 Case Shielding

Case shielding defines the E^3 protection that the actual box or case provides the circuits. Its primary purpose is to reduce the incident plane wave by reflection, with absorption only offering a fraction of additional attenuation at normal thicknesses. Table 3 provides a breakdown of case shielding values by frequency.

Table 3. Case Shielding

Item Description	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
DOUBLE CASE	-18	-17	-16	-15	-14	-14	-13	-13	-12	-12	-12
SINGLE CASE WITH NO UNTREATED HOLES	-14	-13	-12	-11	-10	-9	-8	-7	-7	-6	-6
SINGLE CASE WITH 0.1" UNSHIELDED HOLE	-14	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3
SINGLE CASE WITH 0.3" UNSHIELDED HOLE	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1
SINGLE CASE WITH 1" UNSHIELDED HOLE	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	-1
NO GASKETS AND 2" COVER SCREW SPACE	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-2
NO GASKETS AND 6" COVER SCREW SPACE	-10	-9	-8	-7	-6	-5	-4	-3	-2	-2	-1
10" CRT WITH WIRE SCREEN	-14	-12	-10	-9	-8	-7	-6	-5	-4	-3	-2
10" CRT WITH INTERNAL SHIELDING	-11	-9	-7	-6	-5	-4	-3	-2	-1	-1	-1
10" CRT WITH CONDUCTIVE COVER	-9	-8	-6	-5	-4	-3	-3	-3	-3	-3	-3
SINGLE CASE WITH 3" UNSHIELDED HOLE	-10	-9	-7	-6	-5	-4	-3	-2	-1	-1	-1
SINGLE CASE WITH 10" UNSHIELDED HOLE	-9	-8	-6	-5	-4	-3	-2	-1	-1	-1	-1
METAL PAINTED PLASTIC WITH NO HOLES	-10	-9	-7	-6	-5	-4	-4	-4	-4	-4	-4
METAL FRAME WITH PLASTIC PANELS	-9	-7	-5	-4	-3	-2	-1	-1	-1	-1	-1

Determining the shielding effectiveness of metal cases requires an examination of penetrations, treatments, and seams. When analyzing any metal case, the worst case entry penetration should be used. Relative protective levels of case shielding are described below:

a. No Case Shielding: Sensitive circuits are unprotected or enclosed within a nonmetallic or plastic case, offering no impedance change to the incident wave. Any energy absorption is negligible.

b. Poor Case Shielding: The case is conductive, but openings (e.g., for controls, meters, lights, and ventilation) are not treated for EME penetration (e.g., no screen, conductive glass, honeycomb, or control shaft grounds). Seams are fastened with widely spaced rivets or screws. Either nonconductive gaskets or no gaskets at all are used, and the case is poorly grounded.

c. Medium Case Shielding: This level of shielding might include properly applied thin film with adequately treated penetrations or a metal enclosure with closely spaced screws or rivets. Seams make bare metal contact when assembled and are painted after assembly. There are either EMI gaskets on access covers and screens or similar treatments on ventilation or meter openings. Control shafts are grounded, and the case is grounded (excluding manpack units).

d. Single Case Shielding: This level includes a heavier conductive metal case with welded or rolled overlapping seams and access covers with EMI gaskets that have closely spaced fasteners. All penetrations are treated (e.g., waveguide tubes on control shafts, honeycomb on ventilation, meters, and lights), and the case is grounded.

e. Double Case Shielding: Sensitive circuits are enclosed in two shielding enclosures, one within the other (an IF amplifier in a metal can within a single shield outer case). Both must meet the criteria for single shielding, in (d) above. Both the can and the case must be grounded to drain off energy.

For subsystems mounted in racks, it can be postulated that any additional protection provided by the rack will be negligible in comparison to that provided by the case and the platform. Most racks will only provide attenuation at lower frequencies. The platform and/or case are already providing adequate protection at these frequencies. The values for case shielding in Table 3, therefore, do not take into consideration whether the equipment is rack-mounted.

With respect to frequency dependence, the size of opening discontinuities, like the holes for ventilation or fastener spacing, determines wavelength versus penetration. Penetration of a case by a given frequency incident wave is driven by the size of the largest unprotected opening, since short wavelength signals can penetrate smaller holes. Based on this evaluation, the appropriate case shielding is chosen from Table 3 and entered on line 8 of appendix B.

3.2.4 Cable Shielding

From a susceptibility standpoint, cable shielding is designed to keep interference from the wires that it protects. The degree of protection provided by a cable shield depends on the number of layers of shielding (usually wire braid), the design of the braid, and the method of terminating the braid. Table 4 provides a breakdown of relative protective values for representative cables as they vary with frequency. Based on the cable being used, the appropriate selection is made and the values entered on line 4 of appendix B. If the cable shield is not terminated properly where it enters the subsystem case [i.e., 360 degree peripheral ground via radio frequency interference (RFI) backshell], the cable should be treated as unshielded for frequencies above 1 MHz.

Table 4. Cable Shielding

Item Description	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
NO CABLES	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12
SHIELDED CABLE IN SOLID METAL PIPE	-1	-3	-5	-6	-7	-8	-9	-10	-10	-10	-10
HIGH OPTICAL COVERAGE DOUBLE SHIELD	-1	-3	-5	-6	-7	-8	-9	-9	-10	-10	-10
TYPICAL DOUBLE SHIELD TWISTED PAIR	-3	-3	-4	-5	-6	-7	-8	-7	-7	-7	-7
TYPICAL DOUBLE SHIELD CABLE	0	-2	-4	-5	-6	-7	-8	-7	-7	-7	-7
HIGH OPTICAL COVERAGE SINGLE SHIELD	-1	-3	-5	-6	-6	-6	-6	-5	-5	-5	-5
TYPICAL SINGLE SHIELD TWISTED PAIR	-3	-3	-3	-4	-5	-5	-4	-4	-4	-4	-4
TYPICAL SINGLE SHIELD CABLE	0	-2	-3	-4	-5	-5	-4	-4	-4	-4	-4
TWISTED PAIR	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
CLOSELY SPACED PAIR	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
FLAT RIBBON WITH ONE GROUND RETURN	0	0	0	0	0	0	0	0	0	0	0

3.2.5 Interface Attenuation

Interface attenuation concerns the treatment of interconnecting cables at the point at which they enter the equipment case. A cable with a shielding rating that is lower than the case can be used if provisions are made to properly filter the EMI from the wires contained in the cable before they enter the box. Most filter designs can be defined by the number of poles, roughly approximated by the number of reactive components contained for each wire being filtered. For example, a single capacitor to ground is a one-pole filter. Table 5 provides a representative list of cable interfaces and the attenuation they provide. Although a filter may be efficiently designed and very effective, its proper installation is critical, especially to ensure rejection of signals far from its pass band. Installation considerations refer to measures that are taken to reduce input or output cross talk. These measures include enclosing the filter in its own shielding can, mounting it at a natural shield boundary, and providing drainage to ground for out-of-band energy. Component (R,L,C) filters mounted on open circuit boards may have only

20 to 40 dB of rejection to frequencies two to three times cutoff. Ferrite beads on circuit boards may act as filters, quenching specific frequency bands, but having no effect at other frequencies. For example, a very high frequency (VHF) radio may have excellent selectivity and image rejection in the VHF band, but it may not exclude radar signals or high frequency (HF) energy. The frequency dependence of interface attenuation will be device-specific. As a result, the use of engineering judgement may be necessary when analyzing the cable interface design. Based on the evaluation of cable interface, the appropriate values will be chosen from Table 5 and entered on line 5 of appendix B.

Table 5. Interface Attenuation

Item Description	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
POWER LINE (60/400 Hz) 5 POLE	-6	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
POWER LINE (60/400 Hz) 3 POLE	-6	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
HIGH Q TUNED FILTER	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
POWER LINE (60/400 Hz) 1 POLE	-3	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
AUDIO (<30 kHz) 3 POLE	0	-3	-7	-7	-7	-7	-7	-7	-7	-7	-7
AUDIO (<30 kHz) 1 POLE	0	-1	-3	-4	-5	-5	-5	-5	-5	-5	-5
LOW FREQUENCY (<300 kHz) 3 POLE	0	0	-3	-6	-7	-7	-7	-7	-7	-7	-7
LOW FREQUENCY (<300 kHz) 1 POLE	0	0	-1	-2	-3	-4	-5	-5	-5	-5	-5
HIGH FREQUENCY (<30 MHz) 3 POLE	0	0	0	0	0	0	-3	-6	-7	-7	-7
HIGH FREQUENCY (<30 MHz) 1 POLE	0	0	0	0	0	0	-1	-2	-3	-4	-5
VHF (<300 MHz) 3 POLE	0	0	0	0	0	0	0	0	-3	-6	-7
VHF (<300 MHz) 1 POLE	0	0	0	0	0	0	0	0	-1	-2	-3
NO FILTERS OR ATTENUATION	0	0	0	0	0	0	0	0	0	0	0
SHIELD GROUND CARRIED INTO CASE	2	2	2	2	2	2	3	3	3	3	3

3.2.6 Cable Length

The longer the exposed cable, the more interference it will pick up. Thus, short cable lengths are desirable. Table 6 provides the breakdown of cable length by frequency. Based on the length of the cable being analyzed, the appropriate values are chosen and entered on line 6 of appendix B. If a cable runs close to a large conductive surface and the shield makes a good electrical connection with both the originating and terminating boxes, the values assigned for cable length can be reduced by 1. If the cable leading from the subsystem terminates at a location that is transparent to RF energy (e.g., junction box or part of the platform), the length of the exposed cable leading from that terminating point must be added to the subsystem cable length to determine the overall length of exposed cable.

Table 6. Cable Length

Item Description	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
NO CABLES	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12
1-FOOT CABLES	-10	-8	-6	-5	-4	-3	-2	-1	-1	-1	-1
3-FOOT CABLES	-9	-7	-5	-4	-3	-2	-1	-1	-1	-1	-1
10-FOOT CABLES	-8	-6	-4	-3	-2	-1	-1	-1	-1	-1	-1
30-FOOT CABLES	-7	-5	-3	-2	-1	-1	-1	-1	-1	-1	-1
100-FOOT CABLES	-6	-4	-2	-1	-1	-1	-1	-1	-1	-1	-1
300-FOOT CABLES	-5	-3	-1	-1	-1	-1	-1	-1	-1	-1	-1
1000-FOOT CABLES	-4	-2	-1	-1	-1	-1	-1	-1	-1	-1	-1
3000-FOOT CABLES	-3	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

3.2.7 Circuit Sensitivity

Circuit sensitivity refers to a subsystem circuit's level of sensitivity to the EME. The subsystem's most sensitive circuits will drive this category. Relative levels of circuit sensitivity are described below:

a. Very high sensitivity levels normally apply to the most sensitive portions of radio and radar receivers. They also might apply to extremely sensitive sensors and their associated circuits.

b. High sensitivity levels apply to sensitive analog circuits including: low-level video amplifiers; comparators; synchro-to-digital converters; and high-accuracy timing, regulating, and measurement systems.

c. Medium sensitivity levels cover conventional digital logic and processor circuits, as well as audio amplifiers and most high speed control circuits.

d. Low levels of sensitivity apply to unregulated power supplies and circuits that handle only low frequency AC or DC type controls or logic and are adequately desensitized to interference by internal filtering.

Table 7 provides a detailed breakdown of circuit sensitivity by frequency for a representative list of circuits. Circuit sensitivity can be improved by using multi-layer boards, very short lead lengths, relatively insensitive components, very large scale integration (VLSI) packages, lead bundling, proper dressing, segregation, or any other good design practice. As mentioned earlier, the most sensitive circuits should be chosen for analysis, and intermediate integer values can be used if it appears that one sensitivity level is too low and the next too high. Based on the evaluation of the subsystem's circuitry, the most sensitive circuit values are chosen from Table 7 and entered on line 11 of appendix B.

Table 7. Circuit Sensitivity

Item Description	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
AMPLIFIER, POWER	6	5	3	2	1	1	1	1	0	0	0
AMPLIFIER, AUDIO (PREAMPLIFIER)	7	7	5	4	3	2	1	1	0	0	0
AMPLIFIER, CRYSTAL VIDEO	7	7	7	7	7	7	7	7	6	5	4
AMPLIFIER, RECEIVER, RF/IF (SHIELDED FILTERED)	-3	-2	1	0	0	1	1	1	-1	-1	-2
AMPLIFIER, RECEIVER, RF/IF (UNSHIELDED)	11	11	11	11	11	10	9	8	6	5	4
AMPLIFIER, OPERATIONAL	5	5	5	5	5	4	3	2	0	-1	-2
AMPLIFIER, SENSOR	7	7	5	5	3	3	3	3	2	2	2
AMPLIFIER, TWT (SHIELDED, FILTERED)	-3	-2	-1	1	0	2	3	4	4	4	4
AMPLIFIER, TWT (UNSHIELDED)	11	11	11	11	11	11	11	11	10	10	10
AMPLIFIER, VIDEO (HIGH SENSITIVITY)	11	11	11	12	11	10	9	8	6	5	4
AMPLIFIER, VIDEO (TYPICAL)	5	5	5	5	5	4	3	2	0	-1	-2
CLOCKS, DIGITAL	2	1	1	1	0	-2	-3	-4	-5	-6	-6
COMPARATOR (HIGH SPEED)	7	7	7	7	7	7	7	6	4	3	2
COMPARATOR (LOW SPEED)	7	7	6	5	4	3	2	1	1	1	1
CONVERTER, SYNCHRO TO DIGITAL	7	7	7	7	7	6	5	4	3	2	2
FUEL (VOLATILE)	7	5	3	2	1	0	-1	-2	-6	-6	-6
LOGIC, CMOS (5 MHz)	1	1	1	1	0	-1	-2	-3	-4	-5	-5
LOGIC, CMOS (HIGH SPEED)	2	2	2	2	2	2	1	0	-2	-3	-3
LOGIC, ECL (100K)	3	3	3	3	3	3	3	3	2	1	0
LOGIC, ECL (10K)	3	3	3	3	3	3	3	2	1	0	-1
LOGIC, PMOS/NMOS	1	1	1	0	-1	-2	-2	-4	-5	-5	-5
LOGIC, SCHOTTKY (HIGH SPEED)	2	2	2	2	2	2	2	1	0	-2	-2
LOGIC, TTL (30 MHz)	2	2	2	2	2	2	1	0	-2	-3	-3
LOGIC, TTL HIGH SPEED (100 MHz)	2	2	2	2	2	2	2	1	0	-1	-2
ORDNANCE (HERO SAFE)	-1	-3	-5	-6	-7	-9	-9	-10	-11	-11	-11
ORDNANCE (HERO SUSCEPTIBLE)	1	1	1	3	2	1	0	-2	-4	-4	-5
ORDNANCE (HERO UNSAFE)	3	5	5	5	4	3	1	-1	-3	-4	-5
OSCILLATORS, CRYSTAL CONTROLLED	1	1	1	0	-1	-2	-3	-4	-5	-6	-6
POWER SUPPLY (AC TO DC, UNREGULATED)	-11	-13	-13	-13	-13	-12	-12	-12	-13	-13	-13
POWER SUPPLY (AC TO DC, REGULATED)	-7	-9	-9	-9	-9	-8	-8	-8	-9	-9	-9
POWER SUPPLY (DC TO DC, CONVERTOR)	-3	-5	-7	-8	-8	-8	-8	-8	-9	-9	-9
RELAY, TYPICAL LOW POWER	-1	-3	-5	-6	-6	-6	-6	-6	-7	-7	-7
TIMERS, DIGITAL	1	1	1	0	-1	-2	-3	-4	-5	-6	-6

3.2.8 Weighting Factor

This category allows the PM to include a weighting/safety factor as part of the assessment process. The weighting factor is based on a number of considerations, including: criticality of subsystems; safety implications; cost; impact of failure; confidence in the available data; experience of individual performing the assessment; complexity of the subsystem; or any other element of uncertainty, as determined by the PM. For example, using subsystem criticality as a key factor, a safety of flight subsystem might be given a value of +4, meaning there can be little or no risk of failure. On the other hand, a field telephone set used only for routine message traffic would probably be given a lower value (+1). As one proceeds through each step of this process, uncertainties in the values chosen for a particular category may arise as a result of engineering judgements made, a lack of available data, the complexity of the subsystem, or other factor(s). As a general rule, an additional weighting factor of +1 can be added for each uncertainty encountered, up to +5. The appropriate value is chosen from Table 8 and entered on line 12 of appendix B.

Table 8. Weighting Factor

Item Description	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
NONE	0	0	0	0	0	0	0	0	0	0	0
MINIMAL	1	1	1	1	1	1	1	1	1	1	1
LOW	2	2	2	2	2	2	2	2	2	2	2
MODERATE	3	3	3	3	3	3	3	3	3	3	3
HIGH	4	4	4	4	4	4	4	4	4	4	4
VERY HIGH	5	5	5	5	5	5	5	5	5	5	5

3.2.9 Summary

The first action taken after completing the analysis of all eight categories and entering the appropriate values on the subsystem analysis worksheet (appendix B), is to determine the EME inside the platform. This is done on appendix B by adding the E^3 criteria (line 1) and platform loss (line 2) and entering the result on line 3 (EME inside platform). At this point, it would be useful to examine any available MIL-STD-461/462 test results for the subsystem. For subsystems tested in an EME that is equivalent to or greater than the one indicated by the EME inside the platform on line 3 (reminder: each integer represents 10 dBV/m), determine the frequencies for which the subsystem passed. For those frequencies, enter a "P" in the appropriate column of line 13 (subsystem evaluation). For subsystems tested in an EME that is less than the one indicated on line 3, determine those frequencies for which the subsystem failed. For those frequencies, enter an "F" in the appropriate column of line 13.

The next step after determining the EME inside the platform and examining any MIL-STD-461/462 test results is to determine the overall subsystem shielding effectiveness. This is done by first adding the values for cable shielding (line 4), interface attenuation (line 5), and cable length (line 6) for each of the 11 frequency bands and entering the results on line 7, labeled "cable subtotal". The 11 values on line 7 are then compared to the respective values chosen for case shielding (line 8). The larger or least negative value for each frequency band is then chosen to represent the subsystem shielding effectiveness and is entered on line 9.

The values for subsystem shielding (line 9), EME inside the platform (line 10), circuit sensitivity (line 11), and the weighting factor (line 12) are then added for each frequency band and the total is entered on line 13. The resultant values on line 13 indicate the subsystem's potential susceptibilities to the EME defined by the E^3 criteria. If the value on line 13 is less than 0 (negative), or if a "P" appears, susceptibilities to the EME are not indicated. If the total equals 0, subsystem susceptibilities to the EME cannot be determined without additional analysis or testing. If the total is greater than or equal to +1, or if an "F" appears, susceptibilities to the EME are possible, and the larger the number the more likely that E^3 problems will occur in that frequency band. When the analyses of all the subsystems for a system have been completed, the 11 subsystem evaluation totals for each subsystem are entered onto the system summary worksheet (appendix C).

SECTION 4. IMPACT EVALUATION AND PROGRAM MANAGER ACTION

4.1 IMPACT EVALUATION

If susceptibilities to the EME are predicted in the analysis phase, the PM must make an evaluation of their potential impact on the overall system to determine whether immediate action is required. The PM does this, in conjunction with the E^3 requirements board, by evaluating the impact of the particular subsystem's performance on the total system. Two aspects of this impact need to be considered: (1) Does a degradation of subsystem performance cause a system safety problem? and (2) Will the degradation of subsystem performance result in an unacceptable degradation of the system's mission? If the answer to either of these questions is yes, the EME susceptibility represents a vulnerability that is unacceptable and for which action should be taken by the PM in the near-term. If the answer to both questions is no, the impact can be considered acceptable.

In assessing the system safety impact, the E^3 requirements board will enlist the support of safety experts. If, in the judgement of the PM and the E^3 requirements board, the potential EME susceptibility could cause system failure or degradation that would have serious safety or health consequences (e.g., possible injury or loss of life), the impact must be deemed unacceptable.

In assessing the impact on mission accomplishment, the PM and the E^3 requirements board will review mission priorities and criticality. In addition, they will review system operational and performance characteristics, including effectiveness thresholds. Using this information, they can determine the degree to which the potential EME susceptibilities will degrade system operation and performance and the system's overall ability to perform its mission. If, in their judgement, the system cannot maintain its operational capability or accomplish its mission within an acceptable level of degradation, the impact must be considered unacceptable. Those subsystem susceptibilities that suggest unacceptable system safety or mission impact represent system vulnerabilities that should be addressed by the PM in the near-term. For subsystem susceptibilities whose impact are determined to be acceptable, the PM will continue with his regular E^3 testing program as planned. Additionally, the E^3 requirements board shall review these susceptibilities with respect to the established E^3 criteria to determine whether action is required to comply with AAE Policy Memorandum 91-3.

4.2 PROGRAM MANAGER ACTION

The PM needs to consider immediate action beyond his normal E^3 testing program for those potential EME vulnerabilities that are likely to have an unacceptable system safety or mission impact. As required by AAE Policy Memorandum 91-3, the PM shall establish an accelerated short-term plan to quantify the magnitude of the safety hazard or extent of the mission degradation. As a result of that plan, the PM will determine the type and extent of the action necessary to deal with the indicated EME vulnerability. Depending on the severity of the potential problem and the amount of time and funding available, the action could take the form of a more detailed analysis or additional E^3 testing to quantify more definitively the extent of the EME vulnerability.

In addition, the program manager is responsible for establishing and implementing procedures to ensure that the system will be monitored and maintained properly throughout its life cycle and that it will continue to operate in the EME to which it is exposed. The long-term plan required by AAE Policy Memorandum 91-3 should establish an effective E^3 system evaluation and testing program that will ensure the long-term continuous and safe operation of the system.

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
WASHINGTON, DC 20310-0103

22 JAN 1991

REPLY TO
ATTENTION OF

SARD-DO

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: Army Acquisition Executive (AAE) Policy Memorandum 91-3, Army Electromagnetic Environmental Effects (E3) Program Implementation

The purpose of this memorandum is to provide policy guidance for the Electromagnetic Environmental Effects (E3) Program (enclosed). This revision of the February 26, 1990 E3 Interim Guidance (hereby rescinded) updates policy, delineates responsibilities and clarifies implementation procedures.

The E3 Program's goal is to identify and quantify probable system limitations in its "expected" electromagnetic environment. This will allow the Army to make informed tradeoffs that support system design and/or modification decisions.

The critical players in this effort are: all PMs, project officers or equivalent (Program Sponsors); user representatives; and the Army commands providing materiel development support functions. I expect aggressive leadership from the Program Sponsors to ensure that Army systems safely and effectively perform their missions in the electromagnetic environment.

Stephen K. Conver
Army Acquisition Executive

Enclosure

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CHIEF OF PUBLIC AFFAIRS
INSPECTOR GENERAL

1 January 1991

SUBJECT: Interim Guidance for the Electromagnetic Environmental Effects (E3) Program

1. PURPOSE.

This interim guidance establishes the policy for implementation of the Army Electromagnetic Environmental Effects (E3) Program and the review procedures associated with the program. This policy supersedes the 26 February 1990 version. It will remain in effect until 31 December 1992, at which time all Army systems will have addressed E3 concerns in accordance with this guidance, and appropriate publications will contain necessary instructions to ensure future compliance. E3 will be included in next generation policy and information documents.

2. OBJECTIVE.

The goal of the E3 program is to ensure that Army materiel will accomplish its intended mission in the electromagnetic environment in peace and war. This will be achieved by defining the electromagnetic environment for all Army equipment/systems during operations, training, transport, and storage; identifying expected system degradation caused by the electromagnetic environments; taking action to correct the deficiencies; and incorporating E3 monitoring and controls into the life cycle process. The procurement approval authority for sub-systems and component parts of larger systems and support equipment shall ensure that coordination is made with the Program Sponsors (project/product manager, project officer, item managers, breakout managers or equivalent).

3. SCOPE.

This policy applies to systems, sub-systems, component parts and support equipment from all mission areas acquired under any acquisition strategy. Tailoring of the acquisition strategy to more efficiently meet the E3 program requirements is encouraged. E3 program requirements shall be considered at all system milestone reviews and shall apply for all materiel procurements.

4. PHILOSOPHY.

4.1 It is not practical nor feasible to make every system/subsystem impervious to electromagnetic effects. Program Sponsors, in coordination with user representatives and Army command performing materiel development roles, must conscientiously assess the E3 risk to their system, must build in protection against that risk, or must document the E3 risk as being acceptable. All activities responsible for procuring subsystems, component parts, or support equipment shall ensure that proper coordination is made with the Program Sponsor of the larger system. The most stringent intended use of the equipment will be used to identify system shortcomings. Safety of personnel or munitions is critical. System hardening is generally required to preclude unsafe situations. Program Sponsors must take actions to assure that their items are maintainable at an acceptable level of readiness to allow operation in the expected electromagnetic environment throughout the system's life cycle.

4.2 The generic strategies to counteract E3 are summarized as follows:

4.2.1 Protection (Hardening) -- develop or retrofit by means of shielding, filtering, or protective circuitry;

4.2.2 Operational Fix -- operational avoidance of electromagnetic sources, elimination of particularly susceptible configurations/deployments, or elimination of reliance on susceptible items.

4.2.3 Proliferation -- field the system in sufficient numbers to compensate for expected susceptibility and allow accomplishment of the mission.

4.2.4 Mobility and Dispersion -- mobilize and/or disperse assets to increase survivability and compound targeting difficulties. This method is most effective in preventing interference caused by systems designed to intentionally degrade electronic components.

4.3 Hardening is most cost effective if developed with the system and becomes much more expensive if retrofit of a fielded system is required. Safety related susceptibilities must be treated to reduce the possibility of vulnerabilities to electromagnetic emissions that would make systems unsafe. Safety susceptibilities may be eliminated by hardening, operational fixes, or a combination of the two. Non-safety susceptibilities must not be allowed to degrade system performance to the extent that they reduce the probability of a successful mission below a level acceptable to the user. The probability of mission success depends on a number of factors including E3. All these factors should be weighed to determine the degree of E3 protection to be implemented.

4.3.1 Safety Consequences. Equipment whose failure or degradation by E3 may have safety or health impacts, i.e., possible injury or loss of life, must be hardened to reduce the hazards and preclude catastrophic failure.

4.3.2 Non-Safety Consequences. Equipment failures having no safety impact but affecting mission accomplishment must be protected to an acceptable level as determined by the Program Sponsor, user representative and Army command performing materiel development roles. The Program Sponsor and user representative must agree that there is adequate assurance that the mission can be accomplished.

5. POLICY.

5.1 The user representative will include E3 issues in the initial and all subsequent requirement documents.

5.2 An E3 Requirements Board will be formed consisting of members from the Army command performing materiel development roles (chair person), the Program Sponsor, the user representative, and other necessary advisory members. This board will determine the initial E3 Criteria, evaluate the feasibility of meeting that criteria, conduct mission and hardening level trade-off analyses, and document recommendations to the Program Sponsor. The Program Sponsor shall establish an E3 Criteria acceptable to the Requirements Board as early in the acquisition cycle as possible, usually not later than the milestone I decision. The E3 Criteria will be derived from electromagnetic environments for peace and war, caused by friendly and hostile emitters and natural effects, expected throughout the system life cycle.

5.3 Program Sponsor and user representative shall include these E3 Criteria in applicable acquisition documents, in coordination with appropriate agencies.

5.4 Each Program Sponsor will use the E3 Requirements Board to assess and document, by use of analyses and/or test, that their system meets its E3 Criteria and the potential effects of E3 on system safety/mission accomplishment. Materiel changes, changes in mission, or changes in the threat will require re-evaluation by this board of the system's E3 Criteria and requirements to operate in the electromagnetic environment. This re-evaluation must only be extensive enough to answer concerns of the E3 Requirements Board. The impact of the change on mission accomplishment must be evaluated and a determination made of the acceptability of any system limitations caused by the change.

5.5 The Program Sponsor shall establish a process to maintain E3 protection throughout the system using documentation, training, configuration controls and verification. The E3 protection of each Army system shall be maintained throughout its life cycle as an integral activity of normal maintenance. The E3 requirements shall be developed and incorporated as identifiable sections/chapters of the Maintenance Plan and/or the Integrated Logistic Support Plan for each Army system.

5.6 E3 related incidents (or "presumed" E3 related incidents) shall be reported by maintenance personnel and/or operators at all levels through the established Quality Deficiency Reporting System, by operators through command or Meaconing, Intrusion, Jamming and Interference (MIJI) channels in accordance with AR 103-3 and established frequency management reporting systems. Respondents must be directed by the Program Sponsor/user representative/materiel developer to reference the deficiency as an E3 problem to allow prompt identification and investigation by E3 POCs. The Program Sponsor is responsible for publishing security classification guidance as it pertains to E3 deficiencies.

5.7 The Army Spectrum Manager shall assist the ARSTAF, MACOMs and other Army organizations by advice of trends in very high power emitters as a result of its coordination at Joint, national and international levels; and with awareness of the susceptibility levels identified by the E3 program, ensure that the spectrum management process disseminates appropriate alerts and coordination.

6. IMPLEMENTATION.

Program Sponsors, working through their supporting E3 Requirements Board, will determine an E3 Criteria applicable to their system and develop a plan to ensure that the system continues to meet the criteria. Some systems, primarily those with no electronic content, will not require E3 Criteria. An agreement by all members of the E3 Requirements Board is necessary to determine if a system does not require E3 Criteria. The PEOs or designated commanders are responsible for oversight of systems under their control. ASA(RDA) is responsible for oversight of the Army E3 Program.

6.1 Systems in Acquisition. All systems with a milestone II or equivalent (milestone I/milestone III) decision after 31 December 1990 shall fully comply with the provisions of this policy for that milestone review. This will include defining the expected electromagnetic environment, designing the system to operate acceptably in that environment, scheduling system testing based upon the environment, and establishing a life cycle control process to ensure that the system will continue to operate in its electromagnetic environment. Developmental systems with a milestone II or equivalent (milestone I/milestone III) decision prior to 31 December 1990 will use the fielded system requirements below.

6.2 Fielded Systems

6.2.1 All Acquisition Category I (ACAT I) and Acquisition Category II (ACAT II) programs with a milestone II or equivalent (milestone I/milestone III) decision prior to 31 December 1990 (Appendix C) shall comply with the provisions of this policy by 31 December 1991. This will include: a) defining the expected electromagnetic environment E3 Criteria; b) determining if the environment is likely to create a safety hazard or result in a serious degradation of mission capability, and if so, establishing a short term plan to quantify the magnitude of the safety hazard or the extent of the mission degradation; and c) establishing a long term plan to conduct system evaluation/testing based upon the environment and to incorporate the life cycle control process. This process must ensure that the system will continue to operate in its electromagnetic environment.

6.2.2 All Acquisition Category III and IV (ACAT III & IV) programs with a milestone II or equivalent (milestone I/milestone III) decision prior to 31 December 1990, shall comply with the provisions of this policy by 31 December 1992. This will include: a) defining the expected electromagnetic environment and E3 Criteria; b) determining if the environment is likely to create a safety hazard or result in a serious degradation of mission capability, and if so, establishing a short term plan to quantify the magnitude of the safety hazard or the extent of the mission degradation; and c) establishing a long term plan to conduct system evaluation/testing based upon the environment and to incorporate the life cycle control process. This process must ensure that the system will continue to operate in its electromagnetic environment.

7. RESPONSIBILITIES.

7.1 Assistant Secretary of the Army (Research, Development, Acquisition): act as proponent for the Army E3 Program for policy and standards; provide the Executive Secretary for the E3 General Officer Review Council, chaired by the VCSA; oversee implementation of E3 policy and institutionalization of the Army E3 Program; and ensure revisions of AR 70-1, Systems Acquisition Policy and Procedures, and other publications contain appropriate provisions for the Army E3 program.

7.2 Commanding General, U.S. Army Materiel Command: maintain E3 Oversight Management Office, which will serve as technical proponent for E3 program, policy and standards and as E3 program advisor to ASA(RDA); develop and maintain scientific/engineering personnel, analysis, and test facility resources to accomplish the implementation of E3 policy; ensure coordination is made with Program Sponsors before repair parts, support equipment and other government furnished items are procured; host and provide a chair person for the E3 Requirements Boards at the MSCs providing matrix engineering support to a Program Sponsor; and coordinate preparation of appropriate environmental legal documents and public affairs initiatives in accordance with the National Environmental Policy Act (NEPA) and AR 200-2.

7.2.1 U.S. Army Materiel Systems Analysis Activity: support E3 policy and provide the technical independent evaluator for materiel acquisition programs as designated.

7.2.2 U.S. Army Test and Evaluation Command: support E3 policy and provide the technical tester for materiel acquisitions programs as designated.

7.2.3 U.S. Army Logistics Management College (ALMC): support E3 policy and provides technical training for personnel involved in the research, development, acquisition, and management of Army systems.

7.2.4 Other Major Subordinate Commands: support E3 policy and provide scientific/engineering technical support for material acquisition programs as designated by HQ AMC.

7.3 Commanding General, U.S. Army Training and Doctrine Command: ensure the inclusion of E3 concerns in requirement documents for each Army system; provide members to the various E3 Requirements Boards that will determine the E3 Criteria for systems and conduct trade-offs as necessary, ensuring that the systems can perform assigned missions; and development of curriculum in TRADOC schools for E3 awareness training and training of personnel on the installation, operation and maintenance of Army systems.

7.4 Director of Information Systems for Command, Control, Communications, and Computers: provide the information systems management focal point for the implementation of this policy for assigned systems; and function as the Army Spectrum Manager.

7.5 Deputy Chief of Staff for Operations and Plans: establish policy for the inclusion of E3 in the requirements documents and review documents requiring HQDA approval for E3 essential operational features.

7.6 Deputy Chief of Staff for Intelligence: provide approval and validation of threat E3 documentation for (ACAT I), (ACAT II), and non-major programs and in accordance with AR 381-11.

7.7 Army Surgeon General: responsible for conducting health hazard assessment of electromagnetic radiation in support of RDT&E, conducting medical research to assist the assessment process, providing HQDA level guidance for addressing/evaluating E3 health hazards and ensuring health hazard assessment procedures in accordance with AR 40-10.

7.8 Commanding General, U.S. Army Information Systems Command: implementation of this policy for acquisition of assigned systems; maintains E3 technical activity at subordinate commands; responsible for operating the Propagation Technical Services and the Operational EMC programs for the Army (ODISC4).

7.9 Commanding General, U.S. Army Operational Test and Evaluation Command: as operational evaluator is responsible for ensuring that materiel meets the requirements established in this policy through continuous and comprehensive evaluation of the acquisition process and through operational test and evaluation, prior to full scale production and fielding.

7.10 Commander, U.S. Army Safety Center: monitor the application of system safety throughout the life cycle including the effects of electromagnetic radiation; and provide HQDA level guidance for addressing/evaluating E3 hazards and ensuring risk assessment procedures are in accordance with AR 385-16.

7.11 Program Executive Officer/Program Sponsor: execute and manage the application of policies contained in this interim guidance to achieve the stated objectives for each Army system, regardless of where it may be in its life cycle.

7.12 E3 Requirements Boards: meet as necessary to determine E3 Criteria, determine the impact of materiel, environment or mission changes on the criteria, conduct trade-off analyses, and provide written recommendations to the Program Sponsor.

8. REQUIREMENTS.

The E3 Requirements Board for each system is composed of the Army command performing materiel development roles (chair person), the Program Sponsor, user representative, and other necessary advisory members. The board will identify the range of anticipated electromagnetic environments (including the most stressful) to be encountered. They shall jointly establish the E3 Criteria necessary for the system to operate without degradation in these environments. Any decision not to fully comply with the E3 Criteria is to be treated as a basic inadequacy of the system. Relaxation of E3 Criteria will be considered for approval only when there is an overriding benefit to the government.

8.1 E3 Criteria. E3 Criteria are drawn from the approved projections of: phenomenology; threat and friendly offensive radio frequency (rf) capabilities; tactical and fixed radars; nuclear and non-nuclear EMP effects; tactical and fixed communications and electronics; commercial emitters; broadcast stations; and amateur radio services. The E3 Criteria are based on the predicted electromagnetic environment for peace and war in the intended operation, training, transport, and storage phases of the system, expected throughout the system life cycle.

8.2 Relaxation of E3 Criteria

8.2.1 Justifications. Only the E3 Requirements Board may determine that a relaxation of E3 Criteria is appropriate. Relaxation of E3 Criteria will not be approved if the deficiency would result in a critical mission abort in war-time, an inability to train in peace-time, or a safety problem anytime. If a relaxation of E3 Criteria conflicts with a materiel requirement, a request for change to the requirement must also be approved in accordance with AR 71-9. Relaxation of the E3 Criteria may be justified under the following conditions:

8.2.1.1 Operational Justification. Deployment, use, temporary disconnection, or other means to operationally reduce the E3 threat, in lieu of hardening to higher levels. If a system will not be available for a period of time, an assessment of mission impact will be made for the duration of periods of expected non-availability. The Program Sponsor and user representative must ensure that systems are identified as E3 restricted items and that equipment operators and commanders are made aware of the potential limitations.

8.2.1.2 Proliferation Justification. The quantity required for a normal deployment would allow for attrition due to E3 vulnerability (non-safety related deficiencies only).

8.2.2 Process. The E3 Requirement Board will evaluate The impact of any proposed relaxation on the basis of mission accomplishment and safety. The board will make a written recommendation to the Program Sponsor on whether a relaxation should be pursued. Waivers of nuclear EMP requirements will be submitted in accordance with AR 15-41. The specification waiver/deviation approval process currently in effect will not be changed by this guidance. The following functions will be accomplished for relaxation of E3 Criteria:

8.2.2.1 Program Sponsors: Propose relaxation of E3 Criteria to the E3 Requirements Board for analysis, provided there is compelling cause based on one or more of the above justifications.

8.2.2.2 Army command performing material development roles: Provide technical support for Program Sponsors of systems for which the command has engineering support responsibilities; and provide a technical chairperson for the E3 Requirements Board for those systems.

8.2.2.3 PEO: Resolve any concerns raised by the E3 Requirements Board; and ensure that the Program Sponsor's justification includes evaluation results and a System Safety Risk Assessment (SSRA).

8.2.2.4 E3 Requirements Board: convenes to define the system E3 Criteria, analyze the mission and safety impact of proposed relaxation of E3 Criteria, and makes written recommendations to the Program Sponsor. The board will:

8.2.2.4.1 Perform and review technical analyses, including a System Safety Risk Assessment (SSRA) and Health Hazard Assessment (HHA);

8.2.2.4.2 Validate requests for relaxation of E3 Criteria justification(s) for all systems;

8.2.2.4.3 Provide written recommendations and comments to the responsible Program Sponsor;

8.2.2.4.4 Forward written recommendations and comments to the responsible Program Executive Officer/ Commander having program authority for the system if the concerns of all the members are not resolved by the Program Sponsor;

8.2.2.4.5 Submit unresolved concerns for ACAT I and ACAT II programs and comments to ASA(RDA), Director, Program and Vulnerability Assessment if the concerns are not resolved at the Program Executive Officer/Commander level.

8.2.2.5 ASA(RDA), Director, Program and Vulnerability Assessment: review all unresolved concerns received from E3 Requirements Boards. AMSAA, the Army Safety Center and other activities will provide technical assistance and risk assessment support. The Director, Program and Vulnerability Assessment will initiate an examination of any inconsistencies.

9. TEST AND EVALUATION.

To ensure that Army materiel is in compliance with E3 policy, analysis and testing under the purview of an Army tester and an independent evaluator shall be performed on samples of each Army system, that is required to have E3 Criteria based upon the performance statement of the materiel requirement. Analyses will assess the probable inter-system and intra-system E3 hardness, as well as provide guidance and theoretical pretest predictions. The intent of E3 testing is to use currently scheduled testing to ensure that E3 is fully addressed against the E3 Criteria rather than requiring new or increased testing. Testing may be divided into two categories:

9.1 Developmental Test and Evaluation: There are two distinct types of developmental tests. They are:

9.1.1 Developmental tests and analyses, which are the responsibility of the Program Sponsor, performed at Government laboratories, Government test centers, or equivalent contractor operated facilities, intended to validate analyses, identify E3 which are not amenable to analysis (for example, most non-linear effects), and develop E3 hardening levels. These tests are cooperative in nature in order to identify and resolve problems.

9.1.2 Developmental test and evaluation, which are conducted in the developmental environment by technical personnel under the purview of an Army tester and an independent evaluator. These tests are performed against E3 Criteria and standards developed for the system and may be contractually binding. Facilities performing this class of test must avoid the fact or appearance of conflict of interest.

9.2 Operational Test and Evaluation: tests conducted in an operational environment by operational Army units under the purview of an Army Operational Tester and Independent Operational Evaluator.

10. ARMY SPECTRUM MANAGEMENT AND THE OPERATIONAL EMC PROGRAM.

10.1 The Program Sponsor shall initiate a DD Form 1494, Application for Frequency Allocation, for all spectrum dependent systems in accordance with AR 5-12.

10.2 The Operational Electromagnetic Compatibility (EMC) Program. The Army's Spectrum Manager has the responsibility to support telecommunications (including weapons systems) and electronic warfare (EW). This is accomplished through acquisition of spectrum resources, their efficient use, and the attainment of electromagnetic compatibility. USAISC/USAISEC has the responsibility for providing the Operational EMC and propagation services programs. The Operational EMC program provides quick reaction teams for electromagnetic support/resolution. EMC and propagation engineering support and consultation are also provided for new systems implementation, system upgrades and other C-E system applications. This is a mission funded program and the services are free to all Army users. More information on the services provided by the Operational EMC program are contained in AR 5-12.

10.3 Issues or conflicts with civilian or other government departments, or malfunctions in civil electronic systems alleged to be caused by Army communications, radars, sensors or EW equipment shall be reported promptly to the Army Spectrum Manager.

11. TRAINING.

E3 Awareness Training, in the form of tailorable modules and a video presentation, was integrated into TRADOC courses. An E3 Awareness Training Module (master) will be made available to other MACOMs, upon request. Copies of the E3 video may be requested through local audio visual centers. Whenever possible, E3 topics should be integrated into formal, on-the-job, commercial and specially developed training programs.

12. SYSTEM ENGINEERING MANAGEMENT.

The Program Sponsor shall be responsible for managing the total engineering effort during the life cycle. The Program Sponsor shall assure that system engineering applied to E3 is adequately planned, executed, and evaluated so as to result in E3 protection that meets operational and support needs. E3 requirements validation and risk assessment will be managed as key elements of the system engineering management effort, integral to the overall system acquisition.

13. MAINTAINING OPERATIONAL SYSTEMS.

Appropriate actions must be taken by Program Sponsors, user representatives, materiel developers, breakout managers and item managers to reduce to an acceptable level the risk associated with electromagnetic radiation, throughout the operational life of the equipment. These managers must assure that their items are maintainable in design and are maintained in practice at an acceptable level of readiness to operate in the anticipated electromagnetic environment throughout the life cycle.

13.1 The E3 hardness of each Army system shall be maintained throughout its life cycle as part of normal maintenance. Regardless of the complexity of systems, E3 surveillance concepts should be developed which utilize the lowest practical maintenance level, e.g., visual inspection of grounds, bonds, and shields by operational personnel and minimise the use of highly specialized CONUS based E3 test facilities.

13.2 E3 related incidents (or "presumed" E3 related incidents) shall be reported by maintenance personnel and/or operators at all levels through the established QDR, MIJI or frequency management reporting systems. Respondents must reference the deficiency as an electromagnetic environmental effects problem.

14. HQDA Action Officer OASA(RDA) Major Roddy DSN 227-5584 or Commercial (703) 697-5584.

APPENDIX A: EXPLANATION OF ABBREVIATIONS AND TERMS.

A.1 Analysis - The use of computational or other mathematical resources to assess the effect of the electromagnetic environment on system mission performance.

A.2 E3 Criteria - The E3 Criteria will define a baseline level of protection. It is a subset of the predicted electromagnetic environment to which a system could be designed to prevent degradation in a given theater, on a training mission, during transport, or in a storage configuration. As a minimum, criteria must include critical frequencies (or wavelength), expected duration and field strength (or power density if a propagating wave). Pulse characteristics and modulation characteristics are necessary, if applicable.

A.3 E3 Protection - Implementation of the E3 Criteria on a system by means of shielding, filtering, or protective circuitry.

A.4 Electromagnetic Compatibility (EMC) - Ref. JCS Pub 1. The capability of electrical and electronic systems, equipments, and devices to operate in their intended electromagnetic environment within a defined margin of safety, and at design levels of performance without suffering or causing unacceptable degradation as a result of electromagnetic interference.

A.5 Electromagnetic Environmental Effects (E3) - Reference Joint Chief of Staff Publication 1. The impact of the electromagnetic environment upon the operational capability of military forces, equipment, systems, and platforms. It encompasses all electromagnetic disciplines, including electromagnetic compatibility/electromagnetic interference; electromagnetic vulnerability; electromagnetic pulse; electronic counter-countermeasures, hazards of electromagnetic radiation to personnel, ordnance, and volatile materials; and natural phenomena effects of lightning and p-static.

A.6 Electromagnetic environments - All electromagnetic radiation, manmade and natural, emanating from emitters at the lowest alternating current to the highest radio frequency (RF) are covered; peace-time and war-time; naturally occurring; friendly and hostile; all modes of modulation and spectrum usage.

A.7 Emitter - A source of electromagnetic energy; typically deliberate transmitters, radars, jammers, lightning, static electricity, and inadvertent sources.

A.8 Hardening - See E3 protection.

A.9 Program Sponsor - Generic term for the actual manager of the program at its base level: i.e., the program/project/product manager (PM).

A.10 Susceptible - A system having an observable or measurable effect caused by the electromagnetic environment.

A.11 User Representative - An individual or organization identified for a selected material acquisition program to manage all facets of user input and user actions throughout development, production, and deployment of assigned systems.

A.12 Vulnerable - A system having a transitory or permanent hazard potential or impairment of mission capability caused by the electromagnetic environment.

APPENDIX B: REFERENCES.

The following Army regulations provide the basis for this policy:

- AR 5-12: Army Management of the Electromagnetic Spectrum [Army materiel which either depends on or effects the use of the electromagnetic spectrum will be introduced in the Army only after the results of appropriate EMC analyses have shown the proposed materiel is compatible with the coexisting electromagnetic environment].

- AR 15-41: Nuclear and Chemical Survivability Committee

- AR 40-10: Health Hazards Assessment

- AR 50-5: Nuclear Surety [policy and procedures for positive control of electromagnetic radiation hazards to nuclear weapons and security systems].

- AR 70-1: Systems Acquisition Policy and Procedures [One of the objectives of research, development, & acquisition is to develop and acquire systems meeting user needs that inter-operate with other battlefield systems].

- AR 70-10: Test and Evaluation [requires EW and EMC testing].

- AR 70-60: Nuclear Survivability of Army Materiel [requires consideration of nuclear electromagnetic pulse (EMP) hardening of all Army systems; controls waivers of EMP hardening; establishes life cycle EMP hardness maintenance procedures].

- AR 71-3: User Testing [Test & evaluation of materiel systems are accomplished with typical user operators, crews or units in as realistic environment as possible to provide data].

- AR 71-9: Materiel Objectives and Requirements [requires system performance to be responsive to battlefield conditions for continuous combat (such as full electronic countermeasures, directed energy and E3) and requires consideration of communications, compatibility with existing systems, nuclear survivability including EMP, directed energy survivability, and E3].

- AR 105-2: Electronic Counter-Countermeasures (ECCM)/ Electronic Warfare Vulnerability and Susceptibility [at the earliest possible time prior to the initiation of demonstration/ validation phase and the formalization of system specifications for Full Scale Development, the need for ECCM protection will be specified and supported by the Program Sponsor].

- AR 103-3: Reporting Meaconing, Intrusion, Jamming, and Interference of Electromagnetic Systems [establishes reporting procedures for MIJI incidences for U.S. military electronic systems].

- AR 200-2: Environmental Effects of Army Actions [outlines responsibilities of Army activities].

- AR 381-11: Threat Support to U.S. Army Force, Combat, and Materiel Development.

- AR 385-16: System Safety Engineering and Management.

- AR 525-22: Electronic Warfare Policy [protect systems from electronic warfare; test in the electronic warfare environment].

APPENDIX C: MAJOR SYSTEMS IN ACQUISITION BEYOND MILESTONE II

PEO	SYSTEM
AIR DEFENSE	FAADS LOS-F-H FAADS LOS-R PATRIOT STINGER
ARMAMENTS	SADARM 155 HIP
ARMORED SYSTEM MOD	ABRAMS BFVS
AVIATION	AH-64A CH-47D LONGBOW OH-58D UH-60
COMBAT SUPPORT	FMTV PLS
COMMAND AND CONTROL	AFATDS ASAS CSSCS FAADS C2I MCS
COMMUNICATION	EPLARS GPS JTIDS MSE SINCGARS
FIRE SUPPORT	AAWS ATACMS BLK I GLTR HELLFIRE MLRS SADARM MLRS
INTELL & ELEC WARFARE	JSTARS
AMC PM MINES	WAM-HE

Appendix B: Subsystem Analysis Worksheet

Subsystem: ______________________

Category	Frequency										
	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
1. E^3 Criteria											
2. Platform Loss											
3. EME Inside Platform (Add lines 1 & 2)											
4. Cable Shielding											
5. Interface Attenuation											
6. Cable Length											
7. Cable Subtotal (Add lines 4, 5 & 6)											
8. Case Shielding											
* The larger value of Cable Subtotal (line 7) and Case Shielding (line 8)											
9. Subsystem Shielding*											
10. EME Inside Platform (From line 3)											
11. Circuit Sensitivity											
12. Weighting Factor											
13. Subsystem Evaluation (total of lines 9-12)											

If subsystem evaluation total is greater than +3, subsystem susceptibility to EME is likely.
If subsystem evaluation total is between +1 and +3, susceptibility to EME is possible.
If subsystem evaluation total equals 0, susceptibility to EME cannot be determined.
If subsystem evaluation total is less than 0 (negative), susceptibility to EME is not indicated.

Appendix C: System Summary Worksheet

Subsystem	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz

Appendix D: Caveats and Assumptions

Caveats:

1. This methodology is a first-order mathematical tool and is not a substitute for testing. Its results are order of magnitude and are designed to provide indications of major E^3 problems. If the results show no indications of major problems, the PM should continue with the E^3 testing program as planned. (Page 2)

2. Use of this methodology is optional. Program managers do not need to utilize it if the E^3 requirements board determines that: (1) the system has already been tested to an EME that is equivalent to or greater than its E^3 criteria; or (2) an acceptable alternative methodology is being used. (Page 1)

Assumptions:

1. This methodology assesses E^3 at the system level by focusing on the analysis of its individual subsystems. It is assumed that, if a subsystem shows a susceptibility to the EME, it is a susceptibility of the overall system. It is assumed that there are no synergisms or resonant effects. (Page 2)

2. It is assumed that prior to using this methodology, the PM has already established the system's E^3 criteria. (Page 1)

3. It is assumed that the subsystem being analyzed is entirely contained within its platform and that the subsystem case is properly bonded, adequately grounded, and well maintained. (Page 8)

4. For subsystems mounted in racks, it is assumed that any additional E^3 protection provided by the rack will be negligible in comparison to that provided by the case and platform. (Page 10)

Appendix E: Methodology Development

1. INTRODUCTION

The task assigned for this project was to develop an analytical procedure/methodology by which Army PMs can assess potential EME susceptibilities for systems beyond acquisition Milestone II. This methodology is intended to be purely analytical in nature and does not require additional up-front E^3 testing (prior to normal schedule) before it can be applied. It can be assumed that any prior testing conducted did not provide enough information to obtain a sufficient E^3 assessment of the system. As a result, the PM could select this methodology as a means for identifying major E^3 problems that require exceptional near-term action.

This methodology was developed by a team of engineers experienced in electromagnetic compatibility (EMC). Appropriate reference materials, in conjunction with their judgement and experience, were used to determine those factors which, when taken together, would provide indications of a system's ability to operate in its intended EME. In formulating the concept, the team asked the following questions:

- What do we need to know to determine whether a system will operate in a given EME?
- How do we use that information?
- What questions do we ask when investigating, defining, and resolving E^3 problems?
- Who will be implementing this procedure?
- Can we reduce the data elements into a logical process that will be of value to users?

The answers to these questions provided the foundation for the E^3 assessment methodology. This methodology provides a first-order assessment, and the results will indicate whether major E^3 susceptibilities are anticipated. By pointing out potential areas of E^3 weaknesses, it will provide PMs with a direction for future actions.

2. PURPOSE

This appendix acquaints the user of the methodology with its origin. It presents the major concepts and principles considered and the approach used in integrating them into the methodology.

3. APPROACH

To make the methodology useful for a wide variety of systems, which are mounted on different kinds of platforms and subjected to situation specific EME, it was important to establish a common set of variables. To do that, it was determined that the subsystem would be established as the base element for analysis. It was assumed that the subsystem consists of electronic circuitry, is usually enclosed in a case, and has cabling that connects it to the other parts of the system.

In examining E^3 susceptibility, the team established five categories for analysis:

- E^3 Criteria: The EME in which the system will operate.
- Platform Loss: The shielding effect provided by the shell or outer boundary of the tank, truck, building, or other structure in which the system/subsystem is installed.
- Subsystem Shielding: A composite of case shielding, cable length, cable shielding, and cable entry interface attenuation.
- Circuit Sensitivity: A measure of the sensitivity of the subsystem's circuits to the EME.
- Weighting Factor: A weighting or safety factor that can be applied to the process as an additional safety margin for more critical subsystems, to compensate for a lack of data or experience on the part of the user, or to compensate for other uncertainties.

Each category was researched to determine its role in the overall scheme, characteristics common to other categories, variations occurring within each category, and any other factors that might make the assessment process more effective and usable. Each category can be quantified logarithmically using dB. As will be discussed later in this appendix, the relationship between the different categories allows these dB factors to be added. To further simplify, 10 dB was taken as the basic unit for this assessment. Values were rounded off to the nearest 10 dB to provide whole number weight factors, yielding order of magnitude precision for this first-order analysis. Values that indicate an increase in potential impinging energy (e.g., greater EME, longer cable, more sensitive circuit) are positive. Values that indicate a reduction in impinging energy (shielding) are negative. The weighting factor is either zero or positive, with the greater number compensating for the larger risk or greater uncertainty.

When examining each of the categories to be analyzed, it was determined that, with the exception of the weighting factor, each is frequency dependent. To allow for this, the frequency spectrum was divided into 11 bands as indicated in Section 3. These bands were selected because they represent a fairly uniform spread across the frequency spectrum, from 10 kHz to 10 GHz. It is assumed that the cables and cases being considered are of a fairly low "Q," and resonance effects normally are not very pronounced. Accordingly, spreads indicated in the frequency bands do not show pronounced frequency selectivity.

4. DEVELOPMENT OF THE ANALYTICAL PROCESS

4.1 General Concept

Using Figure 2 as a guide, this paragraph will describe the development of this analytical process. Assuming an established E^3 criteria for the system, the first factor considered was the platform, which provides some degree of shielding from the EME. Taking the platform into consideration determines the EME that has penetrated the platform and that would be applied to both the case and the interconnecting cables of the subsystem under analysis. Penetration of the case and coupling to the cable represent two possible paths that the EME could follow to adversely affect the subsystem circuitry. The worse case (or larger voltage level) of the two for each of the eleven frequency bands was the one used to examine the effect on the internal circuitry of the subsystem. Applying the larger voltage level to the most sensitive circuit(s) then would give an indication of whether the EME defined by the E^3 criteria would have a measurable effect on the subsystem's circuitry. The weighting factor was the final element added to the process, giving the overall subsystem susceptibility to the E^3 criteria in each frequency band.

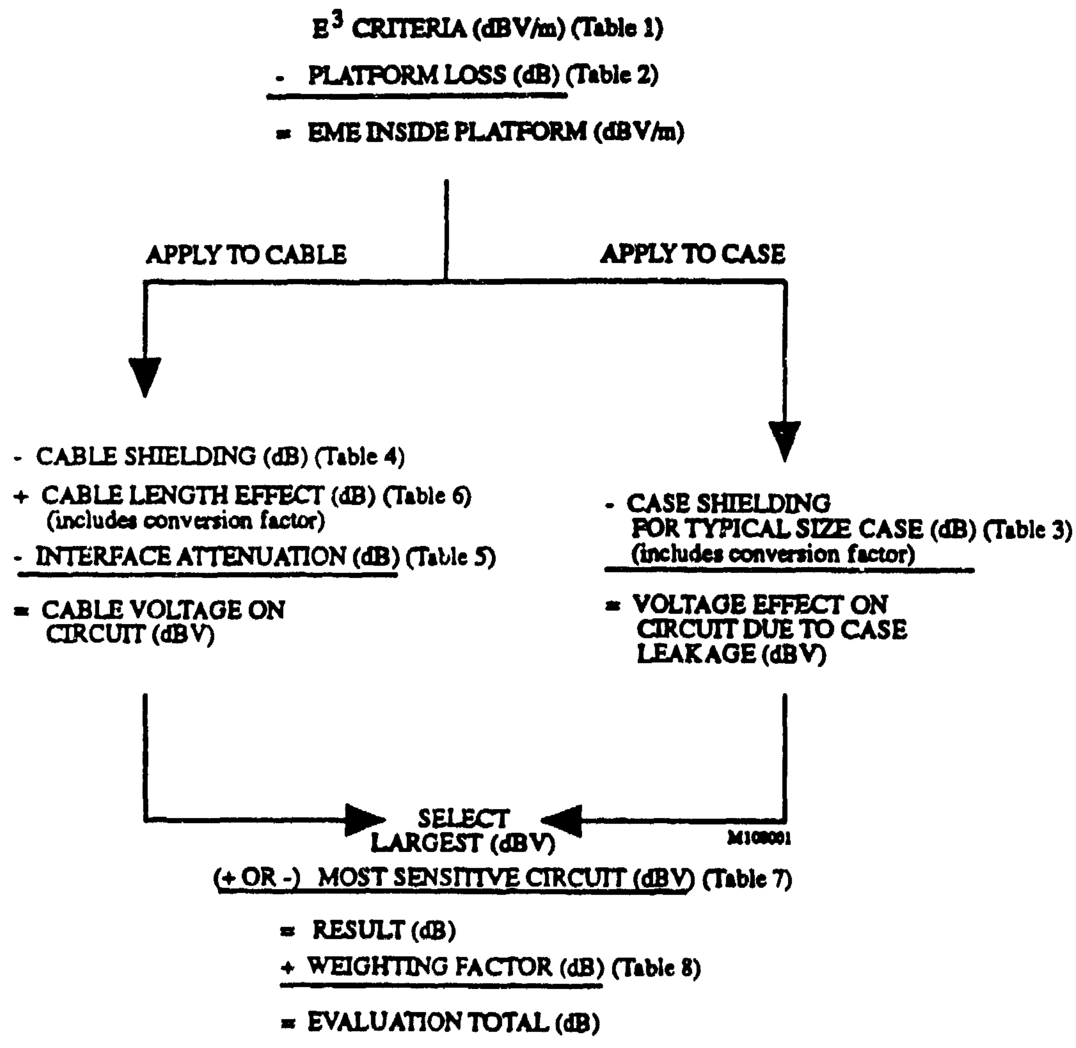

Figure 2. Subsystem Analysis

4.2 Subsystem Analysis

4.2.1 E^3 Criteria

The E^3 criteria is generally defined in V/m. Table 1 relates V/m to decibel volts per meter (dBV/m). The convention was established that each whole EME value represents 10 dBV/m and, if the field strength falls between two EME values, the next highest EME value will be used. For example, a 100 V/m field strength (40 dBV/m) converts to an EME value of 4, and a 320 V/m field strength (50 dBV/m) converts to an EME value to 5. Thus, a 200 V/m field strength (46 dBV/m) will also convert to an EME value of 5.

4.2.2 Platform Loss

Table 2 (platform loss) identifies typical platforms and indicates the degree of protection they provide for each of the 11 frequency bands. In most cases, shielding is very good at the lower frequencies and minimal toward the upper end of the frequency spectrum. Almost any type of conductive structure, regardless of the size of its openings, will provide some degree of shielding at low frequencies. At higher frequencies (e.g., 10 GHz, where the wavelength is much less than one inch), almost any opening or gap will allow passage of the EME into the platform. The values in Table 2 represent tens of dB of protection (e.g., -7 indicates 70 dB of protection provided by that platform at that frequency). The negative values in the table reflect a reduction of the impinging EME. Referring to Figure 2, the E^3 criteria is reduced by platform loss, providing an indication of the EME inside the platform in dBV/m.

4.2.3 Case Shielding

To assess the portion of the EME inside the platform that penetrates the subsystem, the shielding effectiveness of the case was considered independently of the effect of the cables connected to the subsystem. In other words, the case shielding values for the representative case designs listed in Table 3 were determined by assuming that only coupling through the case to the circuitry within was significant. The values are negative, indicating a reduction of effect, and show no greater coupling than -1, worst case.

There is frequency selectivity evident in Table 3 that depends on two factors. First, coupling through apertures (gaps or holes in the case) increases with frequency. Coupling through a hole may be related to the concept of a waveguide cutoff frequency above which energy propagates freely, and below which, is attenuated. The second factor is the length of the circuit wiring inside the case relative to the wavelength. Higher frequencies couple more efficiently, transferring greater energy to the circuit, and inducing higher voltage.

A "conversion" or "antenna" factor is included in the values given in Table 3, since the electromagnetic field (in V/m) coupled to the circuit generates a voltage (V) proportional to that electromagnetic field and dependent on case size and the length of circuit wiring. The conversion factor was determined using a case size of 20 x 30 x 40 cm and 50 cm of printed circuit path and/or interconnecting wire. Referring to Figure 2, subtracting the case shielding effect from the EME inside the platform (dBV/m) results in the voltage level (dBV) applied to the circuit(s) inside the case.

4.2.4 Cable Length

The contribution from the EME inside the platform that couples to the subsystem by means of connected cables was considered independently of case shielding; that is, the values of Table 6 (cable length) and Table 4 (cable shielding) were determined by assuming that there was no coupling through the subsystem case. The electromagnetic field (in V/m) induces a voltage (V) on the cable. As a result, there is an antenna factor, proportional to cable length, included in the values given in Table 6. At the shorter wavelengths (higher frequencies), the effect of the longer cable length is diminished, since the maximum coupling occurs when the cable length is approximately 1/2 wavelength.

4.2.5 Cable Shielding

To determine the values for cable shielding (Table 4), 0 dB baseline levels were used, and it was assumed there was no coupling through the subsystem case. Representative types of cable (listed in Table 4) were analyzed to determine the level of induced voltage applied to the circuit(s) for entry into Table 4 (in tens of dB). As the cable shielding improves the values assigned for each frequency band become more negative, indicating that less of the signal is being coupled to the circuit.

4.2.6 Interface Attenuation

The values shown for interface attenuation in Table 5 (in tens of dB) represent the typical dB attenuation that would be provided for the specific filter indicated in the table if it were placed between the cable conductor and the circuit. The negative values in the table indicate a reduction of the EME. Referring again to Figure 2, applying the EME inside the platform (dBV/m) to the cable results in the voltage level (dBV) applied to the circuit(s) inside the case after considering the effects of cable shielding, cable length and interface attenuation.

4.2.7 Circuit Sensitivity

As indicated in Figure 2, a determination of the worse case, or the larger of the two potential signal levels at the circuit, was made and applied to the most sensitive circuit(s). The circuit sensitivity values in Table 7 (in tens of dBV) are inversely proportional to a circuit's threshold of susceptibility and were developed from a variety of references. For integrated digital logic circuits, the noise susceptibility voltage levels are readily available from data books that fully describe all the circuit parameters. For most analog circuits, the susceptibility levels are not readily available. In these cases, reference literature and practical experience provided information regarding the circuit impedances, the minimum usable input signal levels, the cutoff frequency, and the dB per decade of sensitivity decrease at frequencies above cutoff. For this analysis, the degree of susceptibility was determined in dB above or below 1 volt (0 dBV). If the threshold of susceptibility was less than 1 volt, a positive number was indicated in Table 7, showing that the circuit was more susceptible than the 1 volt reference level. For example, if a circuit's susceptibility was at 0.1 volt (-20 dBV), a value of +2 would be used in Table 7. Similarly, if the circuit susceptibility threshold were higher than 1 volt, a negative number was indicated to show a decrease in susceptibility with respect to the 1 volt reference level. For example, if a circuit's susceptibility was 10 volts (+20 dBV), a value of -2 would be used in Table 7.

4.2.8 Weighting Factor

Lastly, a weighting or safety factor was added to the process. This was done to allow for more critical or complex subsystems, safety or cost considerations, or any other elements of uncertainty. Table 8 (in tens of dB) reflects the range of values that can be chosen (+2 represents 20 dB). Note that there are only positive values for this category; hence, the weighting factor can only increase a subsystem's potential susceptibility to the EME. Adding the weighting factor completes the process and provides the user with the final evaluation total necessary to determine the subsystem's susceptibility to the E^3 criteria in each of the 11 frequency bands.

4.2.9 Evaluation Criteria

To complete development of this analytical process, it was necessary to establish an evaluation criteria. What do the evaluation totals mean? Zero was selected as the dividing line, as the baselines used in developing the process were at the zero dB level. Considering the addition of the weighting factor, the following criteria were adopted to provide a meaningful evaluation of the totals for each frequency band:

Subsystem Evaluation Total	Evaluation
Greater than +3 (30 dB)	Subsystem susceptibility to EME is likely.
Between +1 and +3 (10 to 30 dB)	Subsystem susceptibility to EME is possible.
0 (0 dB)	Susceptibility to EME cannot be determined without further evaluation or testing.
Less than 0 (0 dB)	Subsystem susceptibility to EME is not indicated.

5. REFERENCES

The following reference material, in conjunction with the experience of the team of engineers involved in this project, was used during the development of the analytical process.

Carstensen, R. V. Electromagnetic Interference Control in Boats and Ships, Don White Consultants, Inc., 1981.

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User's Manual, Program #5220, EMC Design and Retrofit to Control Radiated Susceptibility of Equipments and Interconnected Boxes, Version 3.1, Interference Control Technologies, 1989.

User's Manual, Program #5500, EMC Design and Retrofit to Meet Electromagnetic Ambient Threats and Overall Shielding Effectiveness Requirements, Revision 2.11, Interference Control Technologies, 1986.

Variety of manufacturer's technical brochures.

MIL-STD-461C, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference.

MIL-STD-462, Measurement of Electromagnetic Interference Characteristics.

MIL-STD-463, Definitions and System of Units, Electromagnetic Interference and Electromagnetic Compatibility Technology.

MIL-STD-1310, Shipboard Bonding, Grounding and Other Techniques for Electromagnetic Compatibility and Safety.

MIL-STD-1605, Procedures for Conducting a Shipboard Electromagnetic Interference Survey (Surface Ships).

Attachment 3

Electromagnetic Environmental Effects Assessment
Global Positioning System

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3)

ASSESSMENT

GLOBAL POSITIONING SYSTEM (GPS)

for

PROJECT MANAGER GLOBAL POSITIONING SYSTEM

December 1991

Unclassified
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20. ABSTRACT (continue on reverse side if necessary and identify by block number)

This report documents an initial analysis of the Manpack, SLGR and PLGR GPS receivers as to their vulnerability to Electromagnetic Environmental Effects in the worst case operating environment.

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SECURITY CLASSIFICATION OF THIS PAGE (when data entered)
Unclassified

FOREWARD

This is the first Electromagnetic Environmental Effects (E^3) assessment report on the Global Positioning System (GPS) User Equipment (UE). The report identifies E^3 criteria for hand-held ground applications of the Manpack, Small Lightweight GPS Receiver (SLGR), and Precision Lightweight GPS Receiver (PLGR) and assesses the ability of these receivers to function in the electromagnetic environment defined by the E^3 criteria. This report was prepared under the supervision of Mr. Kenneth Brockel and is submitted for your approval.

____
K.H. Brockel
Chairman, C^3 Systems

Date__________________________

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Capt. W. Reiner
TRADOC

Date__________________________

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A. McBean
CED

Date__________________________

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R. Spicer
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Date__________________________

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J. Gamble
C^3 Systems

Date__________________________

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G. Goleski
AVRADA

Date__________________________

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R. Bostock
PM GPS

Date__________________________

Executive Summary

This report represents the GPS E3 Board's initial review of the GPS environment as compared to the baseline user requirements, specifications and standards, and existing test data. The Board's initial review was limited to the ground hand-held applications of the AN/PSN-8, Manpack, Small Lightweight GPS Receiver (SLGR), and Precision Lightweight GPS Receiver (PLGR).

The assessment methodology provided by DA/AMC Staff dated September 1991 was used as a basis for most of the results. However, the Board did discover some shortcomings with the process. The most notable of these was the failure of the methodology to address the problem of in-band emitters. A communications system analysis will be used to complete the assessment for these in-band emitters.

The Board decided to use United States Army Electronic Proving Ground Publication EMETF 91-06-001 dated June 1991 to establish the emitters that GPS would encounter on the battlefield. It is acknowledged that the Europe VI Scenario on which this document is based is outdated. However, the Board believes that it is the only baseline presently certified by the user, test, and acquistion communities. Hence it becomes the logical source for identification of battlefield emitters. The Board recognizes that as new scenarios are developed, these emitters may be relocated and additional work by this Board will be required to establish their impact on GPS. Also the Board will look at new emitters and emitters that are not included in the EMETF document. The most notable of these are the low power close proximity emitters such as hand-held radios and battlefield automated systems. This report represents the inital work of this Board. The success of the E3 process is dependent on establishing a baseline and then continuing the process through the system life cycle. Future focus must be on the E^3 environment that GPS and other systems will encounter in the changing world around us. This will be a major challenge for this Board. We expect our final baseline of GPS will be complete by December 1992. This Board will publish quarterly reports until it is satisfied that the baseline process adequately defines the electromagnetic environment. We will also be assessing impacts and developing solutions to electromagnetic environmental problems revealed by this process.

The support from PEO COMM, PM GPS, TRADOC, AVRADA, Concurrent Engineering Directorate, ARINC Research Corporation, and C3 Systems Directorate has been outstanding. The quality of the Board's work to date has been made possible by the positive attitudes of staff from these organizations.

SECTION 1 INTRODUCTION

1.1. Scope. This report documents the baseline analysis and recommendation of the Army Global Positioning System (GPS) Electromagnetic Environmental Effects (E^3) Requirements Board This Board was set up in compliance with Army Acquisition Executive Policy Memorandum 91-3 dated 1 January 1991. This baseline analysis is an initial effort to assess the worst-case electromagnetic environments (EME) in which GPS User Equipment (UE) must operate and the capability of the UE to function in the worst-case EME. In order to establish a point of departure for the Army GPS E^3 Program, the board decided to limit this initial analysis to hand-held ground applications of the AN/PSN 8, Manpack, Global Positioning System (GPS) receiver, the Precision Lightweight GPS Receiver (PLGR), and the Small Lightweight GPS Receiver (SLGR).

1.2. Board Membership. Composition of the Board is as follows:

Position	Name	Representing	Phone
Chairman	Ken Brockel	C3 SYS	(908) 544-3479
Member	John Gamble	C3 SYS	(908) 544-2500
Member	Gary Goleski	AVRADA	(908) 544-3564
Member	Arnold McBean	CED	(908) 532-3281
Member	Ron Spicer	PEO Comm	(908) 544-2847
Member	Capt. William Reiner	TRADOC	(404) 791-7493
Member	Raymond Bostock	PM GPS	(908) 389-7223

1.3. Organization. This report is organized into five sections. Section 1 is this Introduction. Section 2 contains the Board's recommendations and conclusions. Section 3 presents detailed technical information and analysis supporting the conclusions of Section 2, Section 4. discusses future plans, and Section 5 contains the list of reference documents used in the preparation of this report.

SECTION 2 RECOMMENDATIONS.

2.1 Manpack. Given the small number of Manpacks that are to be fielded and the limited vulnerability predicted, it is the Board's recommendation that no efforts to reduce vulnerability by means of hardware modification be made. Users must, however, be made aware of the possible vulnerability as a consideration in siting these receivers.

2.2 SLGR and PLGR. The Board recommends that the present stringent EMI requirements be retained in the specifications for these receivers and that tests be conducted to insure that these requirements are met.

SECTION 3 DISCUSSION.

3.1. Explanation of Methodology. The methodology used for this analysis and assessment is that outlined in Electromagnetic Environmental Effects (E^3) Assessment Methodology, dated September 1991. This methodology provides a good initial assessment and serves to identify potential problems for further study.

3.2 Electromagnetic Environment. In the context of the Board's deliberations the electromagnetic environment was derived from consideration of any and all emitters and electromagnetic phenomena that constitute a potential cause of malfunction or damage to the GPS receivers under analysis. United States Army Electronic Proving Ground publication Number EMETF 91-06-001, dated June 1991 was used as the source for both friendly and enemy emitters. The emitters detailed in this publication are taken from the Euro VI Scenario. The Euro VI scenario was chosen for this baseline study because of the great body of experience the EMI community already has in using it to model the performance of Army communication systems. EMETF 91-06-001 has separate lists for both friendly and enemy emitters and further subdivides each into mobile and fixed categories. Figures 1 through 4 are taken from EMETF 91-06-001 and summarize the emitters listed in each of the four categories. The field strengths shown in these figures are the field strengths calculated or estimated to exist at a distance of 25 meters from the antenna.

The Board's first task was to derive from the Euro VI data a set of electromagnetic environment criteria. To accomplish this the board made engineering judgments. In some cases the Board chose to altogether disregard emitters on the basis that the receivers under consideration were unlikely to be in the main beam of the emitter antenna. In other cases the Board chose to derate certain emitters. In some cases this derating was based on the improbability of the GPS receiver coming as close as 25 meters to the antenna of the emitter in question. In such cases field strengths at 400 meters were used instead. In other cases the derating represented a conversion from peak to rms field strength. The field strengths given in EMETF 91-06-001 are purported to be average values. However, in some cases the field strength given approaches that for air breakdown. It was the Board's judgment that values in this range were actually peak values. As a first approximation in such cases a 30 dB derating was applied to convert from peak to average (1 millisecond duty cycle). The dotted black line overlaid on each chart represents the E^3 Board's assessment of the worst-case field strengths appropriate for use in formulating E^3 criteria for the ground hand-held GPS receivers that are the subject of this report. The Board believes that despite the derating the worst-case field strengths represented by the dotted line are conservative (i.e., any error is on the high side). Table 1 shows the worst-case values derived from Figures 1 through 4 and their translation into the E^3 criteria used in Tables 2 through 4.

A follow-up evaluation of some of the high level emitters has been conducted using documents other than EMETF 91-06-001. Each such evaluation has served to confirm the Board's judgment that the values given in EMETF 91-06-001 for E-Field strength are peak rather than rms values.

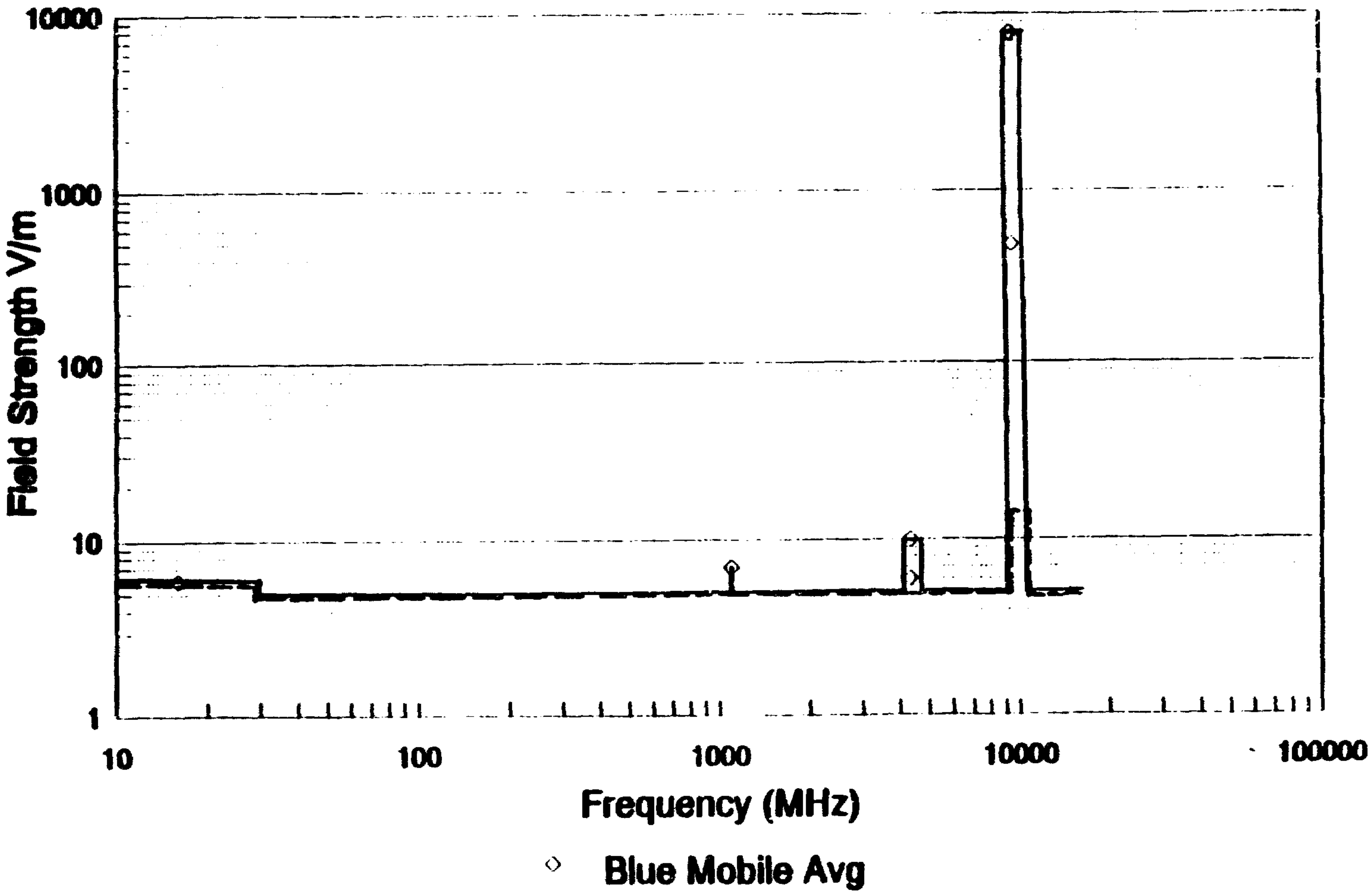
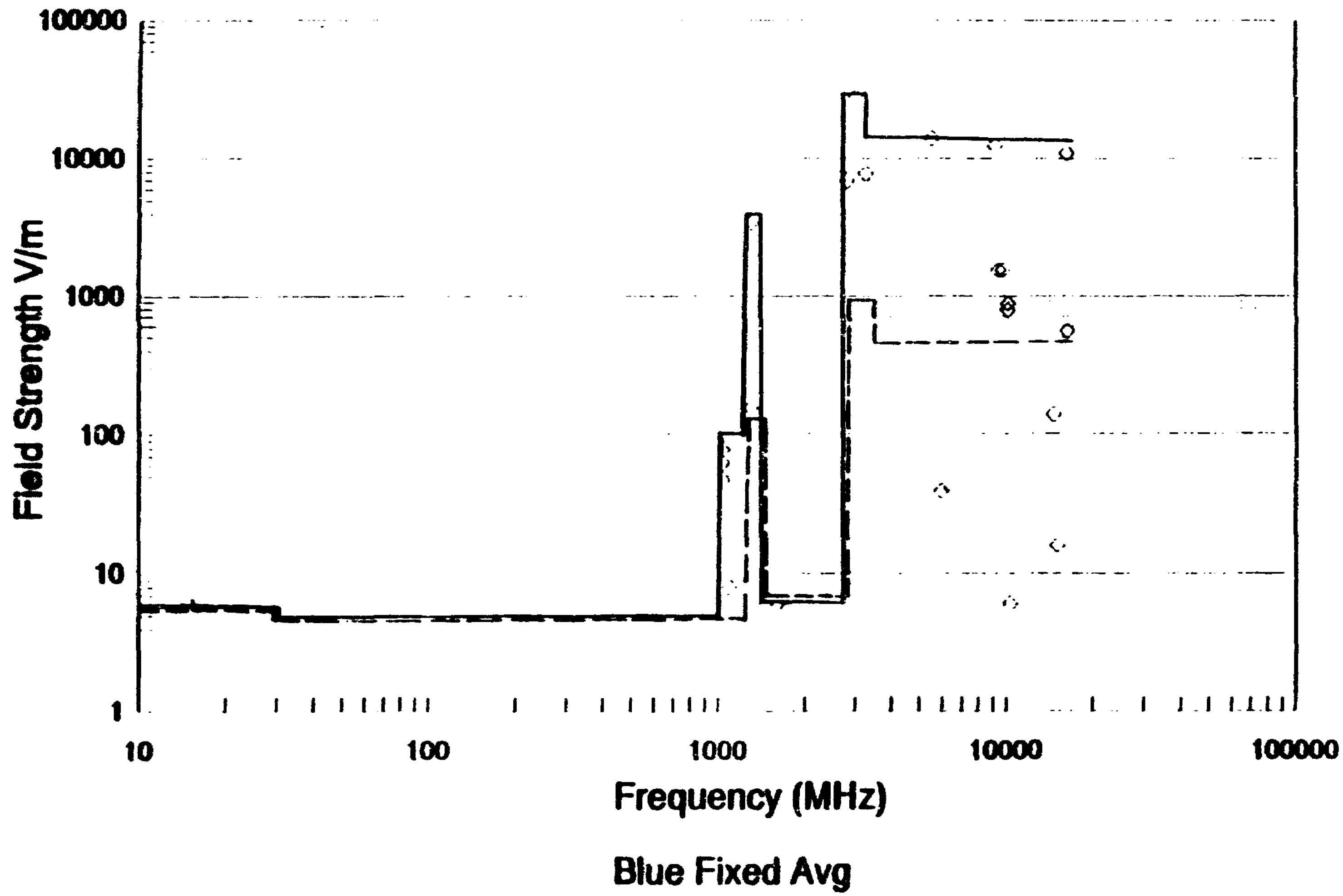

10000
1000
100
10
1
Field Strength V/m
10
100
1000
10000
100000
Frequency (MHz)
Blue Mobile Avg

Figure 1


Field Strength V/m
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1000
100
10
1
10
100
1000
10000
100000
Frequency (MHz)
Blue Fixed Avg

Figure 2

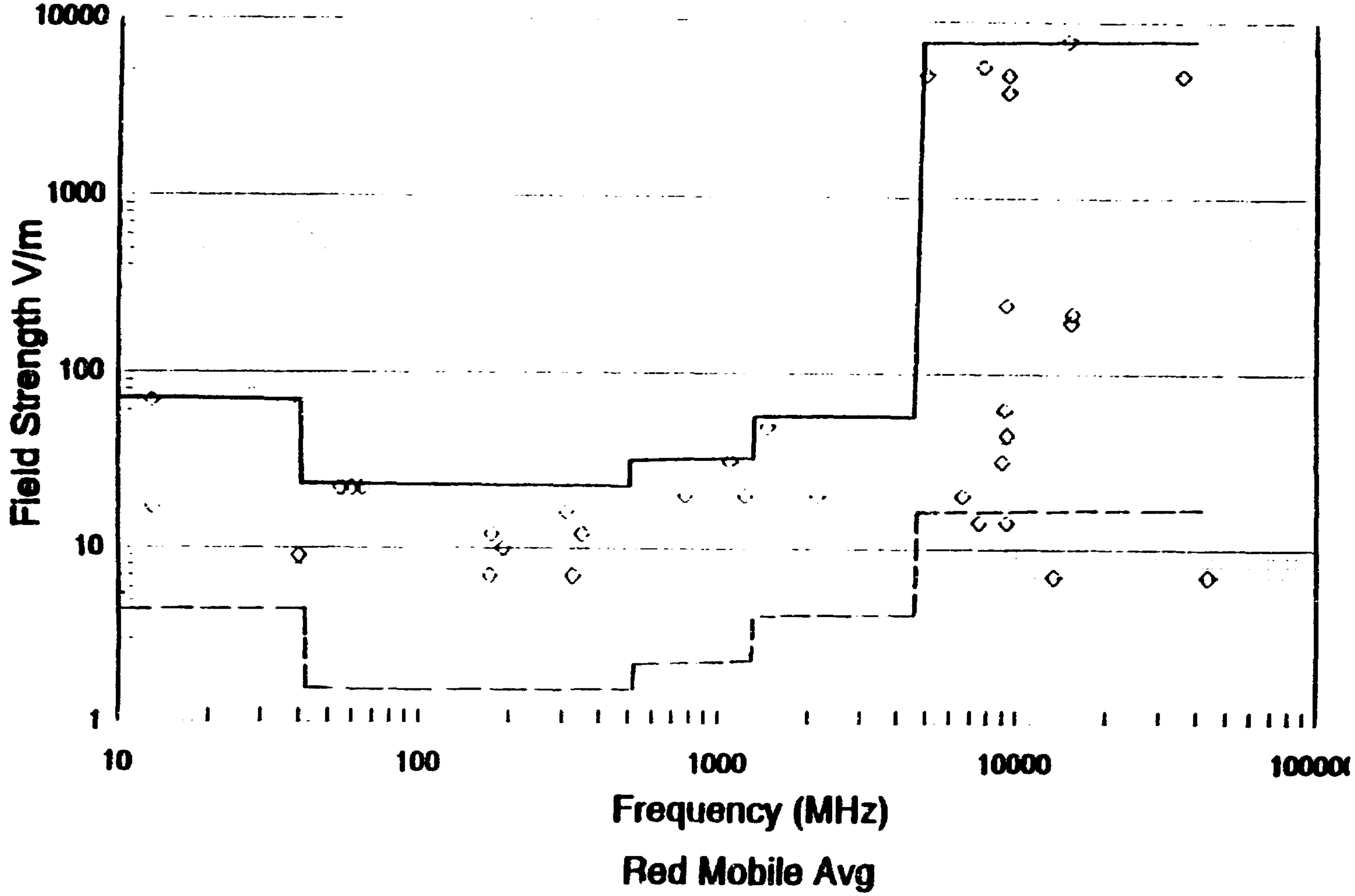
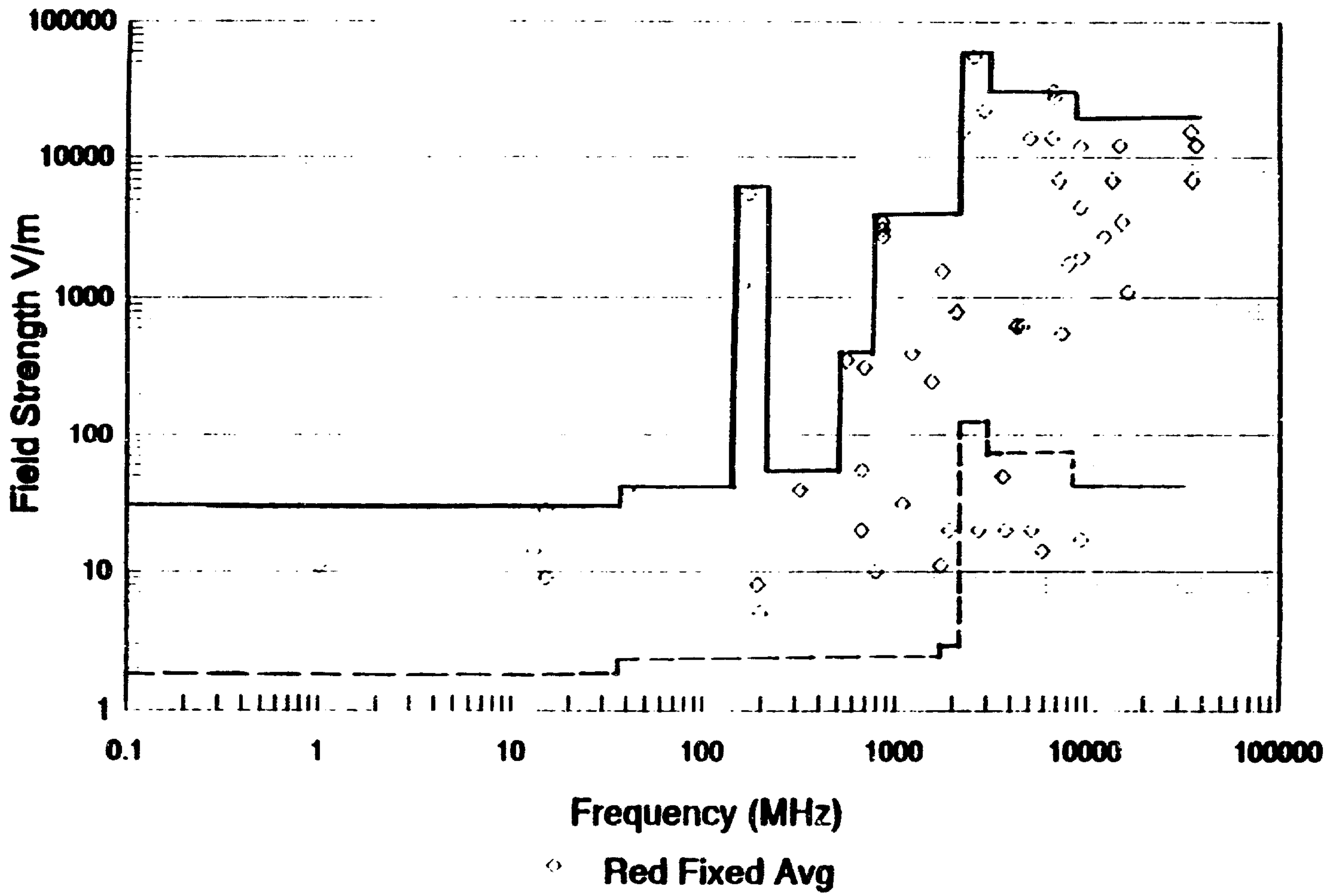

Field Strength V/m
10000
1000
100
10
1
10
100
1000
10000
100000
Frequency (MHz)
Red Mobile Avg

Figure 3



100000
10000
1000
100
10
1
Field Strength V/m
0.1
1
10
100
1000
10000
100000
Frequency (MHz)
Red Fixed Avg

Figure 4

Frequency	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
Blue Mobile	6	6	6	6	6	6	5	5	5	5	15
Blue Fixed	6	6	6	6	6	6	5	5	120	1000	500
Red Mobile	4.5	4.5	4.5	4.5	4.5	4.5	2	2	3	4.5	20
Red Fixed	2	2	2	2	2	2	2	2	2	130	500
Maximum V/m	6	6	6	6	6	6	5	5	120	1000	500
E3 Criteria	2	2	2	2	2	2	2	2	5	6	6

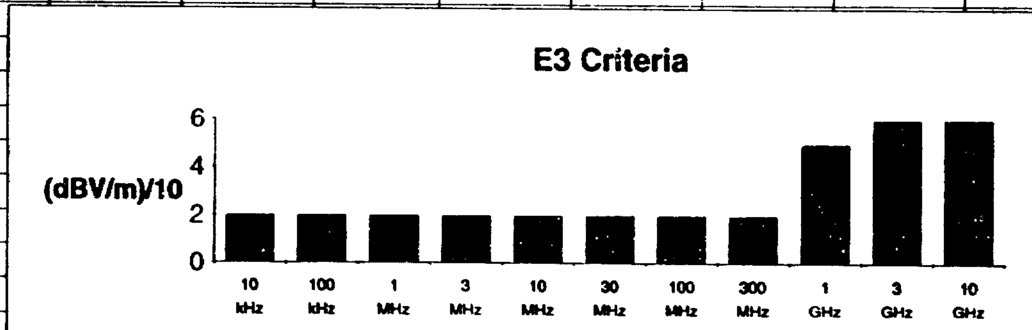


Table 1

Appendix B: Subsystem Analysis Worksheet

Subsystem: Manpack

Category	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
	Frequency										
1. E3 Criteria	2	2	2	2	2	2	2	2	5	6	6
2. Platform Loss	0	0	0	0	0	0	0	0	0	0	0
3. EME Inside Platform	2	2	2	2	2	2	2	2	5	6	6
4. Cable Shielding	0	-2	-3	-4	-5	-5	-4	-4	-4	-4	-4
5. Interface Attenuation	0	0	0	0	0	0	0	0	0	0	0
6. Cable Length	-9	-9	-5	-4	-3	-2	-1	-1	-1	-1	-1
7. Cable Subtotal (Lines 4+5+6)	-9	-11	-8	-8	-8	-7	-5	-5	-5	-5	-5
8. Case Shielding	-10	-9	-7	-6	-5	-4	-3	-2	-1	-1	-1
9. Subsystem Shielding (The larger of Lines 7 and 8)	-9	-9	-7	-6	-5	-4	-3	-2	-1	-1	-1
10. EME Inside Platform (Line 3)	2	2	2	2	2	2	2	2	5	6	6
11. Circuit Sensitivity	1	1	1	1	0	1	1	1	-1	-1	-1
12. Weighting Factor	1	1	1	1	1	1	2	2	2	2	2
13. Subsystem Evaluation	-5	-5	-3	-2	-2	0	2	3	5	6	6
13a. Alt. Subsystem Evaluation	-6	-6	-4	-3	-3	-1	0	1	0	1	1

The alternate subsystem evaluation accounts for the 14 dB of shielding demonstrated in test and assumes a minimum distance of 2.5 Km from the high powered blue emitters.

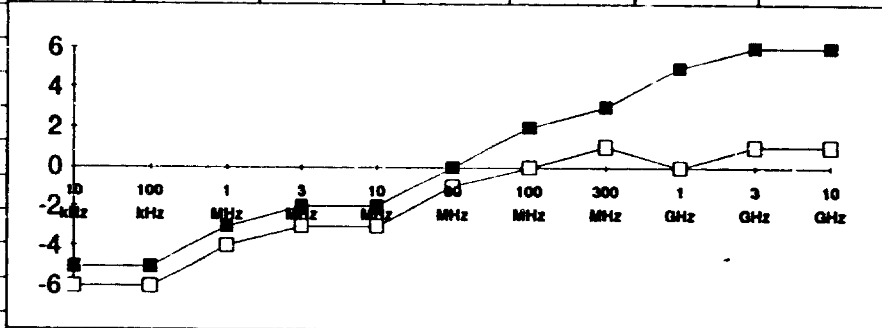


Table 2

Appendix B: Subsystem Analysis Worksheet

Subystem: Precision Lightweight GPS Receiver (PLGR)

Category	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
	Frequency										
1. E3 Criteria	2	2	2	2	2	2	2	2	5	6	6
2. Platform Loss	0	0	0	0	0	0	0	0	0	0	0
3. EME Inside Platform	2	2	2	2	2	2	2	2	5	6	6
4. Cable Shielding	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
5. Interface Attenuation	-3	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
6. Cable Length	-7	-5	-3	-2	-1	-1	-1	-1	-1	-1	-1
7. Cable Subtotal (Lines 4+5+6)	-12	-12	-10	-9	-8	-8	-8	-8	-8	-8	-8
8. Case Shielding	-14	-13	-12	-11	-10	-9	-8	-7	-7	-6	-6
9. Subsystem Shielding (The larger of Lines 7 and 8)	-12	-12	-10	-9	-8	-8	-8	-7	-7	-6	-6
10. EME Inside Platform (Line 3)	2	2	2	2	2	2	2	2	5	C	6
11. Circuit Sensitivity	1	1	1	1	0	1	1	1	-1	-1	-1
12. Weighting Factor	1	1	1	1	1	1	2	2	2	2	2
13. Subsystem Evaluation	-8	-8	-6	-5	-5	-4	-3	-2	-1	1	1

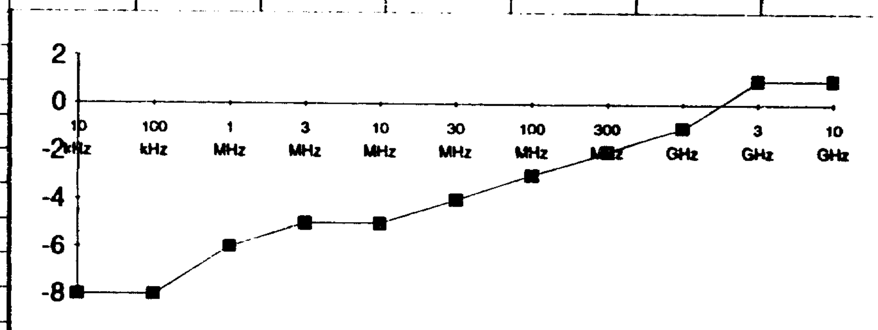


Table 3

Appendix B: Subsystem Analysis Worksheet

Subystem: Single Channel Lightweight GPS Receiver (SLGR)

Category	10 kHz	100 kHz	1 MHz	3 MHz	10 MHz	30 MHz	100 MHz	300 MHz	1 GHz	3 GHz	10 GHz
					Frequency						
1. E3 Criteria	2	2	2	2	2	2	2	2	5	6	6
2. Platform Loss	0	0	0	0	0	0	0	0	0	0	0
3. EME Inside Platform	2	2	2	2	2	2	2	2	5	6	6
4. Cable Shielding	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
5. Interface Attenuation	-3	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
6. Cable Length	-7	-5	-3	-2	-1	-1	-1	-1	-1	-1	-1
7. Cable Subtotal (Lines 4+5+6)	-12	-12	-10	-9	-8	-8	-8	-8	-8	-8	-8
8. Case Shielding	-14	-13	-12	-11	-10	-9	-8	-7	-7	-6	-6
9. Subsystem Shielding (The larger of Lines 7 and 8)	-12	-12	-10	-9	-8	-8	-8	-7	-7	-6	-6
10. EME Inside Platform (Line 3)	2	2	2	2	2	2	2	2	5	6	6
11. Circuit Sensitivity	1	1	1	1	0	1	1	1	-1	-1	-1
12. Weighting Factor	1	1	1	1	1	1	2	2	2	2	2
13. Subsystem Evaluation	-8	-8	-6	-5	-5	-4	-3	-2	-1	1	1

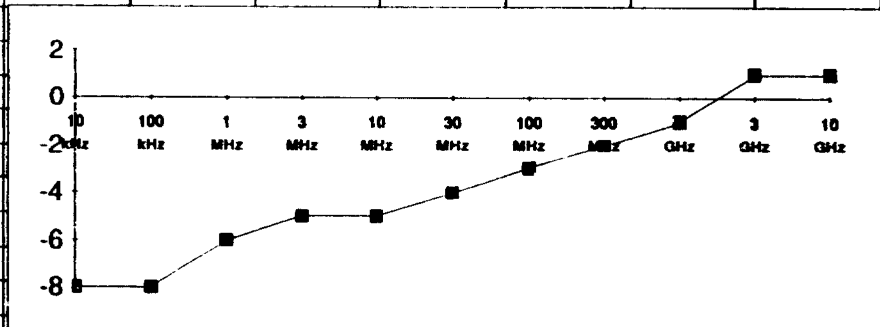


Table 4

3.3. Susceptibility. The Board next applied its judgment to deriving values for the parameters listed on lines 11 and 12 and 2 through 8 of Tables 1 through 3. These values were arrived at utilizing the known parameters for the Manpack and predicted parameters for SLGR and PLGR based on their more stringent EME specification requirements. In each case numbers were assigned by predicting for each parameter the implementation that would be required to attain the degree of hardness specified for the receiver and then using the number assigned to that implementation by the assessment methodology book.

3.4. Assessment. Line 13 of Tables 2, 3, and 4 represents a quantification of the assessments of the Manpack, PLGR, and SLGR respectively. A negative number implies that vulnerability to the predicted EME is not indicated. A number between 0 and 3 implies that vulnerability to the predicted EME is possible. A number greater than 3 implies that vulnerability to the predicted EME is likely.

3.4.1. Manpack. Table 2 indicates that the Manpack has a possible vulnerability to the predicted EME for all frequencies at and above 30 MHz and a likely vulnerability to the predicted EME for all frequencies at and above 3 GHz. This predicted vulnerability goes away if it is assumed that a minimum of 2,500 m displacement from the high powered emitters above 30 MHz is maintained or alternatively that the Manpack is unlikely to be illuminated by the main beam of the emitter. Such an assumption is not unreasonable given the nature of the emitters in question. This assumption will be reviewed with the user community and will be the subject of future deliberations.

Although Table 2 shows a possible susceptibility to E fields in excess of 0 dBV/m, the manpack was actually tested successfully at a level 14 dB higher than that. Therefore it may be inferred that the likely vulnerability shown in Table 2 is only a possible vulnerability.

3.4.2. PLGR and SLGR. Assessment of the PLGR and SLGR, as shown in Tables 3 and 4 indicates that they have a possible vulnerability to the predicted EME for all frequencies at and above 3.GHz. However, a displacement of only 200 m from the high powered emitters at 3 and 10 GHz removes the indicated vulnerability. It must be emphasized, however, that the favorable predictions for SLGR and PLGR are based on the very stringent EMI requirements that are included in the specifications for these receivers. EMI testing must be conducted on each receiver to insure that these requirements are met.

3.4.3. Requirements for Additional Study and Analysis.

3.4.3.1. Electromagnetic Environment. Additional and continuing study will be required to assure the accuracy and realism of the EME used to derive E^3 criteria for ground based GPS receivers. Such study must bring together an intimate knowledge of how and where the GPS receivers are to be used and a detailed knowledge of emitters and their probable locations.

3.4.3.2. In-band Signals. The assessment methodology used by the board does not address the effects of in band signals. The Board viewed this as a significant shortcoming. Accordingly a communications analysis covering the effects of in-band signals is currently in progress.

3.4.3.3. Lightning. It was the Board's judgment that since a lightning strike that would damage the receiver would in all likelihood prove lethal to the operator, there was no further requirement to consider lightning with respect to these receivers in ground applications.

3.4.3.4. Nuclear Effects The effects of scintillation and frequency selective fading following a high altitude nuclear event (HANE) remain to be assessed.

SECTION 4 FUTURE PLANS

GPS receivers will be used in many roles and on many platforms. The matrix of receivers and applications that the GPS E^3 Board will review is shown in Table 5. The Euro VI scenario was used as the baseline for development of the E^3 criteria in this report. However, the Board is continuing to work toward identifying new scenarios that will better reflect the environments that may be encountered in a changing world. The non-linear battlefield of Desert Storm and the drug interdiction and SOF environments will have to be addressed. New emitters and their possible impact on GPS receivers will be evaluated. The key to attaining currency in the assessment process will be the availability of battlefield data. Sources for this data will include the various TRADOC schools, the TECOM Environmental Test Facility, and the LABCOM Vulnerability Assessment Laboratories.

Table 5

	AN/ASN-149	MAGR	SLGR	PLGR	AN/PSN-8/VSN-9
Ground Hand-held			X	X	X
Ground Vehicular		X	X	X	X
Air	X	X	X	X	

The next GPS E^3 Report for Army GPS UE will be published in April 1992. It will address the following issues:

- Ground vehicular applications
- The South West Asia EME
- The base AH-64/UH-60 EME
- A more detailed review of the high powered emitters in the 3-10 GHz band.
- Communications analysis for in-band emitters.
- Nuclear effects

SECTION 5 BIBLIOGRAPHY

1. Electronic Proving Ground Publication, EMETF 91-06-001, dated June 1991

2. Army Acquisition Executive Policy Memorandum 91-3 dated 1 January 1991

3. Electromagnetic Environmental Effects Assessment Methodology dated September 1991

4. Specification for NAVSTAR Global Positioning System (GPS) Precision Lightweight GPS Receiver (PLGR), GPS Joint Program Office Specification Number ss-M/V - 500, Revision A, dated 16 October 1991

5. Specification for NAVSTAR Global Positioning System (GPS) Small Lightweight GPS Receiver (SLGR), GPS Joint Program Office Specification Number ss-M/V - 600, Second Draft, dated 15 October 1991

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
WASHINGTON, DC 20310-0103

22 JAN 1991

REPLY TO
ATTENTION OF

SARD-DO

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: Army Acquisition Executive (AAE) Policy Memorandum 91-3, Army Electromagnetic Environmental Effects (E3) Program Implementation

The purpose of this memorandum is to provide policy guidance for the Electromagnetic Environmental Effects (E3) Program (enclosed). This revision of the February 26, 1990 E3 Interim Guidance (hereby rescinded) updates policy, delineates responsibilities and clarifies implementation procedures.

The E3 Program's goal is to identify and quantify probable system limitations in its "expected" electromagnetic environment. This will allow the Army to make informed tradeoffs that support system design and/or modification decisions.

The critical players in this effort are: all PMs, project officers or equivalent (Program Sponsors); user representatives; and the Army commands providing materiel development support functions. I expect aggressive leadership from the Program Sponsors to ensure that Army systems safely and effectively perform their missions in the electromagnetic environment.

Stephen K. Conver
Army Acquisition Executive

Enclosure

DEPARTMENT OF THE ARMY
HEADQUARTERS US ARMY COMMUNICATIONS-ELECTRONICS COMMAND
RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
FORT MONMOUTH, NJ

REPLY TO
ATTENTION OF

AMSEL-RD (70) 5 JUN 1991

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: Electromagnetic Environmental Effects (E3) Policy Implementation within CECOM

1. Reference Memorandum, AMCDE-PQ (70-a) dated 14 Feb 91 Subject: Army Electromagnetic Environmental Effects (E3) Program, with enclosure, "Army Acquisition Executive (AAE) Policy Memorandum 91-3, Army Electromagnetic Environmental Effects (E3) Program Implementation " (Encl 1).

2. The referenced policy requires the acquisition manager to establish an E3 Requirements Board. That board is composed of "members from the Army command performing materiel development roles (chairperson), the Program Sponsor, the user representative, and other necessary advisory members."

3. The chairperson of the E3 Requirements Board will be provided by the RDEC organization providing the basic functional support to the acquisition manager. The individual named will be a GM-14 or GM-15. Support in the frequency allocation process, and EMI/EMC consulting services will continued to come from the Electromagnetic Environments Division, Center for C3 Systems. Funding for participation in the E3 Requirements Board activities should be covered by modification to the functional support agreements.

4. The CECOM E3 POC is Paul Major, X42334, DSN 995-2334, AMSEL-RD-C3-EM-F.

5. CECOM Bottom Line: THE SOLDIER.

Encl
as

ANTHONY V. CAMPI
Director, CECOM Center for Research, Development and Engineering Center